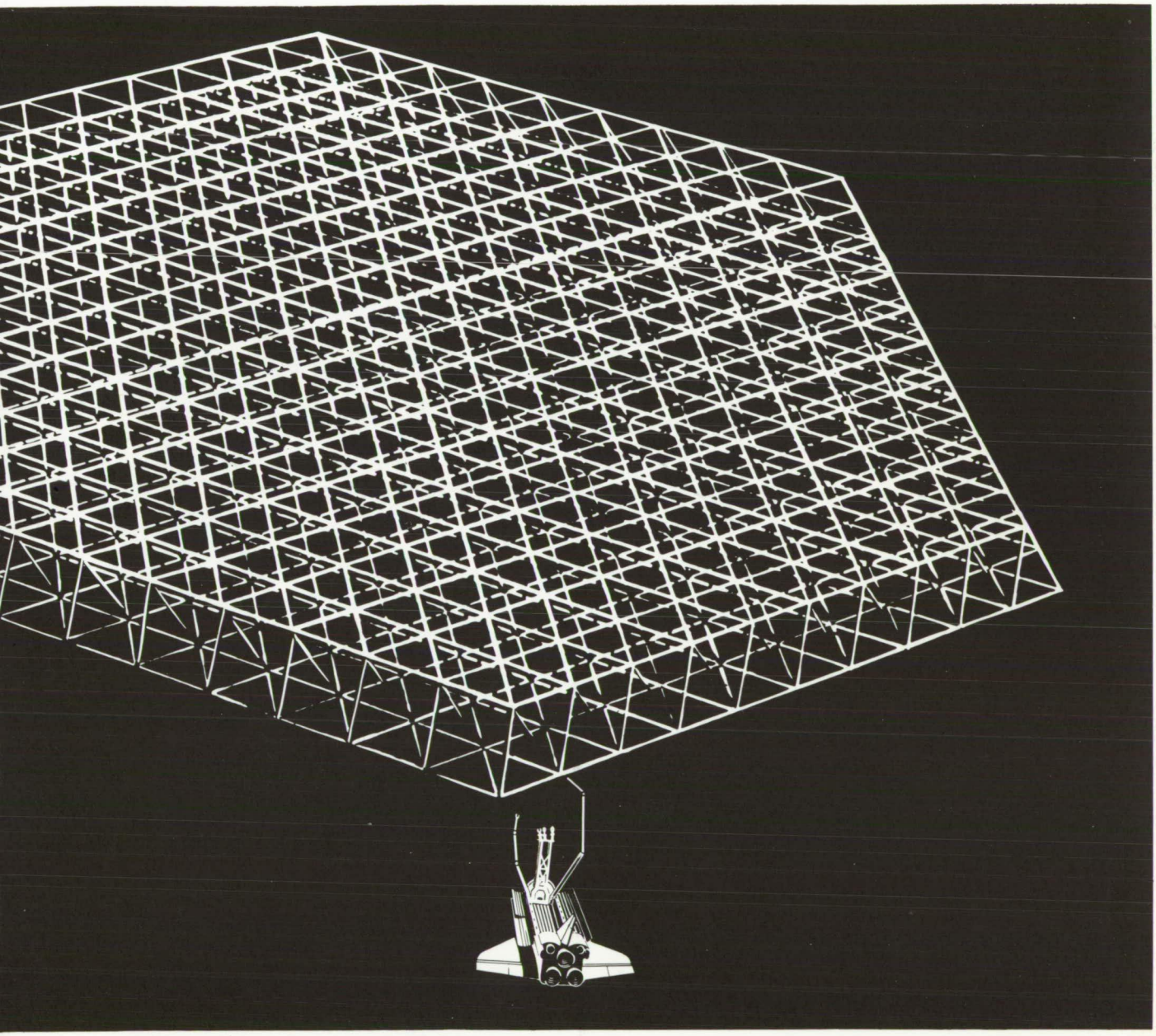
NASA

Technology for Large Space Systems

A Special Bibliography with Indexes

NASA SP-7046(03)
July 1980

National Aeronautics and Space Administration



NASA SP-7046(03)

TECHNOLOGY FOR LARGE SPACE SYSTEMS

A Special Bibliography
With Indexes

Supplement 3

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced between January 1, 1980 and June 30, 1980.

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*

NASA Scientific and Technical Information Branch 1980
National Aeronautics and Space Administration
Washington, DC

INTRODUCTION

This special bibliography is designed to be helpful to the researcher and manager engaged in developing technology within the discipline areas of the Large Space Systems Technology (LSST) Program. Also, the designers of large space systems for approved missions (in the future) will utilize the technology described in the documents referenced herein.

This literature survey lists 217 reports, articles and other documents announced between January 1, 1980 and June 30, 1980 in *Scientific and Technical Aerospace Reports (STAR)* and *International Aerospace Abstracts (IAA)*.

The coverage includes documents that define specific missions that will require large space structures to achieve their objectives. The methods of integrating advanced technology into system configurations and ascertaining the resulting capabilities is also addressed.

A wide range of structural concepts are identified. These include erectable structures which are earth fabricated and space assembled, deployable platforms and deployable antennas which are fabricated, assembled, and packaged on Earth with automatic deployment in space, and space fabricated structures which use pre-processed materials to build the structure in orbit.

The supportive technology that is necessary for full utilization of these concepts is also included. These technologies are identified as Interactive Analysis and Design, Control Systems, Electronics, Advanced Materials, Assembly Concepts, and Propulsion. Electronics is a very limited field in this bibliography, primarily addressing power and data distribution techniques.

This issue of the bibliography will also contain citations to documents dealing primarily with the Solar Power Satellite System (SPS) as will subsequent issues.

The reader will not find references to material that has been designated as "limited" distribution or security classified material. These types of documents will be identified by the LSST Program Office, and a separate listing will be distributed to selected recipients.

A Flight Experiments category and a General category complete the list of subjects addressed by this document.

The selected items are grouped into eleven categories as listed in the Table of Contents with notes regarding the scope of each category. These categories were especially selected for this publication and differ from those normally found in *STAR* and *IAA*.

Each entry consists of a standard bibliographic citation accompanied by an abstract where available. The citations and abstracts are reproduced exactly as they appeared originally in *STAR* and *IAA* including the original accession numbers from the respective announcement journals. This procedure accounts for the variation in citation appearance.

Under each of the eleven categories, the entries are presented in one of two groups that appear in the following order:

1) *IAA* entries identified by accession number series A80-10,000 in ascending accession number order;
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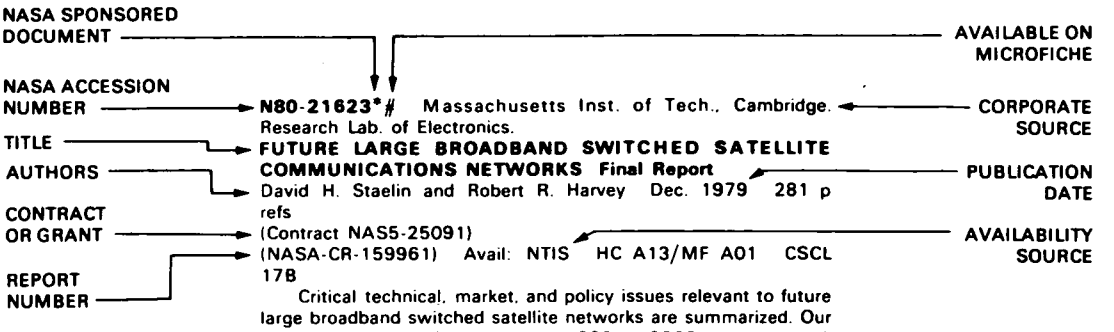
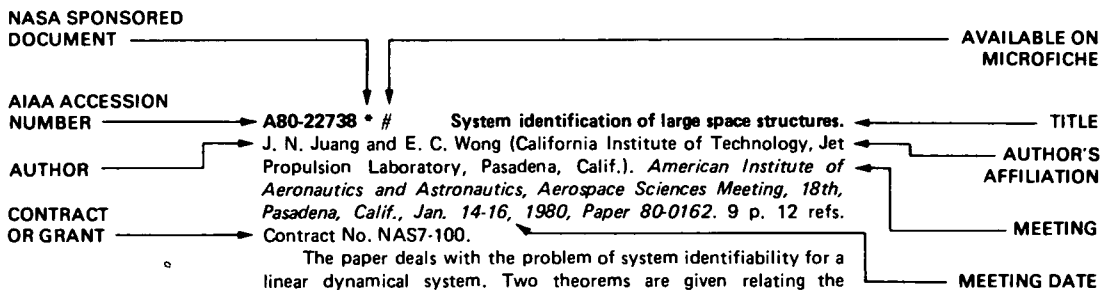


Critical technical, market, and policy issues relevant to future large broadband switched satellite networks are summarized. Our market projections for the period 1980 to 2000 are compared. Clusters of switched satellites, in lieu of large platforms, etc., are shown to have significant advantages. Analysis of an optimum terrestrial network architecture suggests the proper densities of ground stations and that link reliabilities > 99.99% may entail less than a 10% cost premium for diversity protection at 20/30 GHz. These analyses suggest that system costs increase as the 0.6 power of traffic. Cost estimates for nominal 20/30 GHz satellite and ground facilities suggest optimum system configurations might employ satellites with 285 beams, multiple TDMA bands each carrying 256 Mbps, and 16 ft ground station antennas. A nominal development program is outlined. E.D.K.

TYPICAL CITATION AND ABSTRACT FROM *IAA*



The paper deals with the problem of system identifiability for a linear dynamical system. Two theorems are given relating the sufficient condition of system identifiability for certain linear structures to the total number of inputs and outputs. The principle of least squares, that seeks the minimization of a cost function is employed to carry out the system identification process. To illustrate the concept of the paper, a structural model of a beam with point masses is examined. Parameter identification methods are studied and a random search technique is introduced. V.T.

TECHNOLOGY FOR LARGE SPACE SYSTEMS *A Special Bibliography (Suppl. 3)*

JULY 1980

01 SYSTEMS

Includes mission requirements, focus missions, conceptual studies, technology planning, and systems integration.

A80-14335 Perspectives of telecommunication satellite systems development (Perspectives d'évolution des systèmes de télécommunications par satellite). A. M. Hieronimus, G. Berretta (ESA, Paris, France), and M. Guionnet (Centre National d'Etudes Spatiales, Paris, France). In: Space, space telecommunications and satellite radio broadcasting: Objectives for the next decade; International Conference, Toulouse, France, March 5-9, 1979, Lectures. Toulouse, Centre National d'Etudes Spatiales, 1979, p. 343-359.

The development of communications and broadcasting by satellite will be governed by competition between space and other techniques, and the growth of requirements with simultaneous limitations imposed by the available frequency spectrum. The possible effects of interconnecting the systems on their design and interrelationship are described based on a study of the effect of these developments on the concepts of possible missions. Interconnection between homogeneous and nonhomogeneous systems can be achieved on large, common platforms; these would be space stations or a number of smaller satellites connected by intersatellite links. The trend will be toward national and international systems dimensioned to the available launchers for maximum economy, and if large platforms assembled in orbit are built for multimission and leasing, they will coexist with many specialized optimized missions. A.T.

A80-14338 Future satellite communications. B. I. Edelson, R. J. F. Fang, and W. L. Morgan (COMSAT Laboratories, Clarksburg, Md.). In: Space, space telecommunications and satellite radio broadcasting: Objectives for the next decade; International Conference, Toulouse, France, March 5-9, 1979, Lectures. Toulouse, Centre National d'Etudes Spatiales, 1979, p. 391-401. 9 refs.

The development of communications satellite technology is reviewed, showing a substantial increase in capacity of the present larger and more complex satellites. Also, earth stations have become smaller, more efficient, and flexible. Satellite systems now provide international regional, and domestic communications for telephone, television, facsimile, and data traffic. A global maritime system is in operation. Numerous special purpose systems are being developed for future use. Developments now in progress will lead to more complex multifrequency satellites in the 1980s with smaller special purpose earth stations and all-digital transmission systems. Satellite-switched TDMA will be introduced, along with onboard processing. V.P.

A80-14350 Communication satellite evolution during the 1980's. L. Templeton and C. L. Cuccia (Ford Aerospace and Communications Corp., Palo Alto, Calif.). In: Space, space telecommunications and satellite radio broadcasting: Objectives for the next decade; International Conference, Toulouse, France, March 5-9, 1979, Lectures. Toulouse, Centre National d'Etudes Spatiales, 1979, p. 579-596.

Technologies in process and under space qualification for the communications satellites of the 1980s are outlined. Attention is given to the technological improvements for the Intelsat V satellite, which will provide a near doubling of Intelsat IVA capacity for the same general in-orbit mass, a body-stabilized space platform adapted to carry antenna systems capable of transmitting contoured beams to the earth's surface, and a flexible basic bus which can accommodate maritime packages and INSAT satellite equipment. Major advances allowing capacity increases including multibeam antennas, frequency reuse, TDMA, SS-TDMA and regenerative repeaters are presented, and the intended use of Ariane, with a greater launch capacity, is pointed out. Means for component weight reduction, including the use of graphite epoxy composite materials, and mass efficiency improvement are indicated, and multiple-feed, large aperture antennas to provide contoured beams are noted. A.L.W.

A80-14789 * Space platforms for NASA - Opportunity or pitfall. W. J. Cuneo, Jr. and D. P. Williams, III (NASA, Office of Aeronautics and Space Technology, Space Systems Div., Washington, D.C.). In: Space - The best is yet to come; Proceedings of the Sixteenth Space Congress, Cocoa Beach, Fla., April 25-27, 1979. Cocoa Beach, Fla., Canaveral Council of Technical Societies, 1979, p. 4-54 to 4-77.

The paper describes NASA efforts to determine if platform to pool payload services are cost effective. It is shown that the platform concept originated from the short Shuttle life on orbit, the Shuttle capability to assemble aggregating structures, and the belief that economics might be obtained from shared services and repair. In addition, about eighty payloads in NASAs future were identified for consideration. Attention is given to platform configurations produced by contractor and in house studies, noting that comparative cost studies are currently being done. M.E.P.

A80-16437 # System interfaces of large platforms. F. Runge (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.). *American Astronautical Society, Annual Meeting, Los Angeles, Calif., Oct. 29-Nov. 1, 1979, Paper 79-265.* 17 p.

Science and applications space platforms will provide cost-effective accommodations for many Shuttle-era payloads that have common requirements for long-duration low earth orbit flight and support. The paper reviews interfaces between platforms and related system elements, such as payloads, power system, Shuttle, propulsion units, data relay satellites and ground operations. Many interfaces influence the selection of concepts for platform configuration or operation. Interface subjects include payload shape, quantity and accommodations, Shuttle cargo bay stowage, manipulation berthing for activation/loading, attitude control, data handling, drag-makeup, payload viewing, cryo-cooling, and servicing. The discussion reveals that all platform system interfaces must be carefully defined and analyzed for sensitivity to impacts before final design conclusions can be reached for all elements involved. S.D.

A80-18313 * # Operational factors affecting microgravity levels in orbit. R. E. Olsen and J. Mockovciak, Jr. (Grumman Aerospace Corp., Bethpage, N.Y.). *American Institute of Aeronautics*

and Astronautics, Aerospace Sciences Meeting, 18th, Pasadena, Calif., Jan. 14-16, 1980, Paper 80-0317. 7 p. Contract No. NAS8-32390.

Microgravity levels desired for proposed materials processing payloads are fundamental considerations in the design of future space platforms. Disturbance sources, such as aerodynamic drag, attitude control torques, crew motion and orbital dynamics, influence the microgravity levels attainable in orbit. The nature of these effects are assessed relative to platform design parameters such as orbital altitude and configuration geometry, and examples are presented for a representative spacecraft configuration. The possible applications of control techniques to provide extremely low acceleration levels are also discussed. (Author)

A80-20349 * A new phase for NASA's communications satellite program. D. K. Dement (NASA, Office of Advanced Communications Research and Applications, Washington, D.C.). *Satellite Communications,* vol. 4, Jan. 1980, p. 16-19.

NASA's research in communications satellite technology is discussed, including orbit-efficient techniques and applications by the commercial sector. Attention is given to expanding the capacities of the C-band (6-4 GHz) and the Ku-band (14-11 GHz), opening the Ka-band (30/20 GHz), broadly applied 're-use' of the spectrum, and developing multibeam spacecraft antennas with on-board switching. Increasing wideband services in video, high-speed data, and voice trunking is considered, as are narrow-band systems that may be used for data collection or public safety, with possible expansion to a thin-route satellite system. In particular, communication for medical, disaster, or search-and-rescue emergencies may be met by the integration of a satellite service with land mobile communications via terrestrial radio links. Also considered is a large geostationary platform providing electrical power, thermal rejection, and orbital station-keeping for many communications payloads. J.P.B.

A80-25918 * # Narrowband system activities in the NASA communications program. S. H. Durrani (NASA, Goddard Space Flight Center, Greenbelt, Md.). In: ICC '79; International Conference on Communications, Boston, Mass., June 10-14, 1979, Conference Record. Volume 1. Piscataway, N.J., Institute of Electrical and Electronics Engineers, Inc., 1979, p. 15.4.1-15.4.5. 9 refs.

The objective of NASA's narrowband system activities is to identify, develop, and test the technology needed for future commercial satellite-aided mobile communications systems. Desired characteristics include low service cost, efficient spectrum utilization, and compatibility with terrestrial systems. Ongoing effort includes system concept definition and market analysis. A typical system would need a large spaceborne antenna with 50 to 100 beams, each 0.5 to 0.7 degree wide, onboard switching and processing, linear solid-state amplifiers, and low-cost user terminals. The paper describes current studies and discusses future NASA plans in this field. (Author)

A80-25975 * The use of geostationary platforms for future U.S. domestic satellite communications. S. Fordyce (NASA, Washington, D.C.) and R. Stamminger (Future Systems, Inc., Gaithersburg, Md.). In: ICC '79; International Conference on Communications, Boston, Mass., June 10-14, 1979, Conference Record. Volume 3. Piscataway, N.J., Institute of Electrical and Electronics Engineers, Inc., 1979, p. 49.4.1-49.4.5.

Quantitative analyses of the relative costs and utilization of the available geostationary orbital arc and radio spectrum allocations between large spacecraft platforms and future individual satellites used for communications in the U.S. and the Atlantic Basin are presented. Attention is given to the high capacity and the switching capabilities of the platforms, and the frequency ranges (6/4, 14/12, and 30/20 GHz) at which they can operate. In addition, characteristics of conventional satellites, earth station design, and the connectivity of satellite systems are discussed. J.P.B.

A80-26304 The potential development of Spacelab towards the space stations. E. Vallerani (Aeritalia S.p.A., Naples, Italy). *British Interplanetary Society, Journal (Space Technology),* vol. 33, Apr. 1980, p. 138-159. 11 refs.

The potential development of the Shuttle/Spacelab system and Spacelab to meet the requirements of space commercialization and industrialization and possible later colonization is discussed. The present Space Transportation System, comprising the Space Shuttle and Spacelab, and its projected performance and missions are presented, and the requirements of future users for longer orbital durations, higher onboard power, increased heat rejection capabilities and computer memory, and greater Instrument Pointing System flexibility are indicated. The NASA and ESA follow-on development programs to meet these projected requirements are outlined, and the concepts of an advanced captive Spacelab, a free-flying Spacelab module, and a Spacelab module as an element of a complex space platform or space station are examined in detail. A.L.W.

A80-26785 Integrating large space stations into telecommunications networks. W. L. Morgan (COMSAT Laboratories, Clarksburg, Md.). In: EASCON '79; Electronics and Aerospace Systems Conference, Arlington, Va., October 9-11, 1979, Conference Record. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1979, p. 64-68. 5 refs. Research sponsored by the Communications Satellite Corp.

Large space stations (Orbital Antenna Farms) promise lower communications costs through the economy of scale of combining multiple missions in orbit and the simplification of earth stations. Placing the switching centers in orbit (instead of on the ground) may permit telephone calls and data transmission to be routed along network-optimized routes. The impact of this approach (coupled with onboard regeneration and remodulation) on the design of TDMA earth stations and network operations is analyzed. (Author)

A80-29550 # A third generation communication satellite concept. D. E. Koelle and W. Kleinau (Messerschmitt-Bölkow-Blohm GmbH, Ottobrunn, West Germany). In: Communications Satellite Systems Conference, 8th, Orlando, Fla., April 20-24, 1980, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1980, p. 185-191. (AIAA 80-0505)

The paper deals with the third generation of communication spacecraft characterized by mass values beyond 2000 kg and power level above 3 kW. The GEO-SPAS concept is described including platform design and GEO-SPAS capabilities and performance. The economic advantages of a platform concept are outlined. It is noted that Shuttle launch costs are minimized as well as propulsion system costs. V.T.

A80-29551 * # Developing the concept of a geostationary platform. W. T. Carey (NASA, Marshall Space Flight Center, Huntsville, Ala.), R. M. Bowman, and G. R. Stone (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Communications Satellite Systems Conference, 8th, Orlando, Fla., April 20-24, 1980, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1980, p. 192-197. 6 refs. Contract No. NAS8-33527. (AIAA 80-0506)

A geostationary platform concept with a proliferation of low-cost earth stations is discussed. Candidate platform concepts, servicing, life, and Orbital Transfer Vehicle (OTV) options are considered. A Life Cycle Costing model is used to select the minimum cost concept meeting program criteria. It is concluded that the geostationary platform concept is a practical and economical approach to providing expanding communication services within the limitations imposed by the available frequency spectrum and orbital arc. V.T.

A80-29553 # European multipurpose telecommunication satellite - Development plans. B. L. Herdan (ESA, Noordwijk,

Netherlands). In: Communications Satellite Systems Conference, 8th, Orlando, Fla., April 20-24, 1980, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1980, p. 205-215. (AIAA 80-0508)

Results of an ESA market survey are summarized along with the reasons which lie behind the decision of ESA Member States to proceed with the definition phase of a large multipurpose satellite. A platform design solution is outlined together with some examples of derivative configurations. The payload to be associated with the first flight model is discussed. V.T.

A80-29579 # **A projection of the development of high capacity communications satellites in the 1980s.** R. J. Rusch and C. L. Cuccia (Ford Western Development Laboratories, Palo Alto, Calif.). In: Communications Satellite Systems Conference, 8th, Orlando, Fla., April 20-24, 1980, Technical Papers.

New York, American Institute of Aeronautics and Astronautics, Inc., 1980, p. 412-418. 9 refs. (AIAA 80-0544)

It is noted that the need for higher capacity communications satellites in the 1980s and 1990s will require new approaches to satellite design and space segment configuration. Several alternative design concepts are reviewed. A new approach is presented in which the satellite payload is distributed between several spacecraft without requiring satellite interlinks, master control satellites, or large space structures. Attention is given to the advantages of this approach and a comparison is made with the features of other advanced design approaches. M.E.P.

A80-29581 # **Evolution of fixed service communication satellite systems in the 1980's.** G. Berretta (ESA, Directorate of Planning and Future Programmes, Paris, France). In: Communications Satellite Systems Conference, 8th, Orlando, Fla., April 20-24, 1980, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1980, p. 425-432. 6 refs. (AIAA 80-0547)

Countries with advanced space industries are faced with the need to make decisions in the next few years due to the development time required to develop a new generation of space communications. An analysis is made of the factors that will encourage the introduction of such a new generation. Attention is given to the evolution of satellite systems and a specific representative example is described. Emphasis is placed on the potential market of European interest. Consideration is also given to the problems of large multimission platforms, and it is concluded that a rapid evolution towards large space structures is doubtful. M.E.P.

A80-32511 *# **Just over the horizon in space.** I. Bekey (NASA, Washington, D.C.) and J. E. Naugle. *Astronautics and Aeronautics*, vol. 18, May 1980, p. 64-76.

The article surveys some of the concepts introduced and examined by a New Concepts Symposium convened by the NASA Advisory Council recently. Results are reported from the symposium's eight working groups: astrophysics, climate, communications and navigation, energy, large structures, planetary exploration, propulsion and transportation, and telefactors. M.E.P.

N80-13066*# Teledyne Brown Engineering, Huntsville, Ala. Space Programs Div.

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY PRELIMINARY REQUIREMENTS FOR SPACE SCIENCE AND APPLICATIONS PLATFORM STUDIES Final Report

Nov. 1979 108 p

(Contract NAS8-32711)

(NASA-CR-161346; SP79-MSFC-2391) Avail: NTIS HC A06/MF A01 CSCL 22A

Needs and requirements for a free flying space science and applications platform to host groupings of compatible, extended mission experiments in earth orbit are discussed. A payload model which serves to define a typical set of mission requirements in the form of a descriptive data base is presented along with experiment leval and group level data summarizations and flight schedules. The payload descriptions are grouped by technology into the following categories: communications, materials (long term effect upon), materials technology development, power, sensors, and thermal control. A.W.H.

N80-18075*# Brown Engineering Co., Inc., Huntsville, Ala. Space Systems Dept.

STRAWMAN PAYLOAD DATA FOR SCIENCE AND APPLICATIONS SPACE PLATFORMS Final Report

Jan. 1980 214 p

(Contract NAS8-32711)

(NASA-CR-161376; SP80-MSFC-2403) Avail: NTIS HC A10/MF A01 CSCL 22A

The need for a free flying science and applications space platform to host compatible long duration experiment groupings in Earth orbit is discussed. Experiment level information on strawman payload models is presented which serves to identify and quantify the requirements for the space platform system. A description data base on the strawman payload model is presented along with experiment level and group level summaries. Payloads identified in the strawman model include the disciplines of resources observations and environmental observations. A.W.H.

N80-21623*# Massachusetts Inst. of Tech., Cambridge. Research Lab. of Electronics.

FUTURE LARGE BROADBAND SWITCHED SATELLITE COMMUNICATIONS NETWORKS Final Report

David H. Staelin and Robert R. Harvey Dec. 1979 281 p refs

(Contract NAS5-25091)

(NASA-CR-159961) Avail: NTIS HC A13/MF A01 CSCL 17B

Critical technical, market, and policy issues relevant to future large broadband switched satellite networks are summarized. Our market projections for the period 1980 to 2000 are compared. Clusters of switched satellites, in lieu of large platforms, etc., are shown to have significant advantages. Analysis of an optimum terrestrial network architecture suggests the proper densities of ground stations and that link reliabilities > 99.99% may entail less than a 10% cost premium for diversity protection at 20/30 GHz. These analyses suggest that system costs increase as the 0.6 power of traffic. Cost estimates for nominal 20/30 GHz satellite and ground facilities suggest optimum system configurations might employ satellites with 285 beams, multiple TDMA bands each carrying 256 Mbps, and 16 ft ground station antennas. A nominal development program is outlined. E.D.K.

02
INTERACTIVE ANALYSIS AND DESIGN

Includes computerized technology design and development programs, dynamic analysis techniques, thermal modeling, and math modeling.

A80-13183 **The use of modal coupling techniques in the dynamic qualification of large space structures (Der Einsatz modaler Koppelverfahren bei der dynamischen Qualifikation grosser Raumfahrtstrukturen).** A. Bertram and H. Hüners (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Institut für Aeroelastik, Göttingen, West Germany). *DFVLR-Nachrichten,* Nov. 1979, p. 24-27. In German.

It is noted that plans for the use of the Space Shuttle include the construction of reflectors and solar power satellites in orbit. Attention is given to the special problems that arise with the qualification of large space structures. It is expected that large space structures will have a low degree of stiffness which will make them more sensitive to stresses encountered in orbit. Such deflection is undesirable in antennas, for instance, which require a high degree of contour accuracy. The use of the modal coupling technique allows the determination of such behavior by means of a second order linearized differential equation which considers junction point deflection as a function of time. M.E.P.

A80-20905 * **Multilevel modeling of the space construction base.** F. D. Chichester (Bendix Corp., Guidance Systems Div., Teterboro, N.J.). In: Modeling and simulation. Volume 10 - Proceedings of the Tenth Annual Pittsburgh Conference, Pittsburgh, Pa., April 25-27, 1979. Part 5. Pittsburgh, Pa., Instrument Society of America, 1979, p. 1853-1858. Contract No. NAS8-32660.

A mathematical model representing a flexible space vehicle in terms of interconnected discrete masses is recast into hierarchical form to facilitate the application of multilevel control techniques. The model's state equations are temporarily decoupled by utilization of a set of coordination equations. A hierarchical form of the model is constructed with the set of coordination equations at the top of the hierarchy and the set of decoupled scalar state equations in the bottom level. (Author)

A80-22738 * # **System identification of large space structures.** J. N. Juang and E. C. Wong (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 18th, Pasadena, Calif., Jan. 14-16, 1980, Paper 80-0162.* 9 p. 12 refs. Contract No. NAS7-100.

The paper deals with the problem of system identifiability for a linear dynamical system. Two theorems are given relating the sufficient condition of system identifiability for certain linear structures to the total number of inputs and outputs. The principle of least squares, that seeks the minimization of a cost function is employed to carry out the system identification process. To illustrate the concept of the paper, a structural model of a beam with point masses is examined. Parameter identification methods are studied and a random search technique is introduced. V.T.

A80-31670 # **A global Ritz method for reduced-order modeling of a flexible dish antenna.** L. Meirovitch (Virginia Polytechnic Institute and State University, Blacksburg, Va.) and R. Lindberg (U.S. Navy, Naval Research Laboratory, Washington, D.C.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 209-235. 10 refs.

A global Ritz method for reduced-order modeling is developed for the eigensolution of a flexible spaceborne dish-type antenna. The system energy equations are discretized by expressing the elastic displacements of the antenna in terms of a finite set of space dependent admissible functions multiplied by time dependent generalized coordinates. The formulation allows the eigenvalue problem for the structure to be decoupled into separate eigenvalue problems for various types of vibrations. The resulting natural frequencies and modes of the antenna model are compared with results from a NASTRAN finite element analysis of the structure. (Author)

A80-31814 * **Dynamics of rotationally periodic large space structure.** T. J. McDaniel and K. J. Chang (Iowa State University of Science and Technology, Ames, Iowa). *Journal of Sound and Vibration,* vol. 68, Feb. 8, 1980, p. 351-368. 24 refs. Grant No. NsG-1372.

The analysis of large area rotationally periodic space structures presented in the paper combines the finite element method, transfer matrix procedures, approximation methods, and periodic structure analysis to obtain computational efficiency. The computations used in the analysis indicate that additive damping mechanisms can be evaluated from the frequency response of the structure. The transient response can also be obtained from the frequency response to complete the dynamic analysis. V.T.

N80-18946*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EXPERIMENTAL RESULTS ON PLASMA INTERACTIONS WITH LARGE SURFACES AT HIGH VOLTAGES
Norman T. Grier 1980 12 p refs Presented at 18th Aerospace Sci. Meeting, Pasadena, Calif., 14-16 Jan. 1980; sponsored by AIAA
(NASA-TM-81423; E-346) Avail: NTIS HC A02/MF A01 CSCL 20I

Multikilowatt power levels for future payloads can be more efficiently generated using solar arrays operating in the kilovolt range. This implies that large areas of the array at high operating voltages will be exposed to the space plasma environment. The resulting interactions of these high voltage surfaces with space plasma environments can seriously impact the performance of the satellite system. The plasma-surface interaction phenomena were studied in tests performed in two separate vacuum chambers, a 4.6 m diameter by 19.2 long chamber and a 20 m diameter by 27.4 m long chamber. The generated plasma density was approximately 1x10 to the 4th power/cu cm. Ten solar array panels, each with areas of 1400 sq cm were used in the tests. Nine of the solar panels were tested as a composite unit in the form of a 3x3 solar panel matrix. The results from all the tests confirmed small sample tests results: insulators were found to enhance the plasma coupling current for high positive bias and arcing was found to occur at high negative bias. A.R.H.

N80-19153*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
DEVELOPMENT OF ELECTROMAGNETIC ANALYSIS METHODS FOR LARGE APERTURE ANTENNAS
C. R. Cockrell, L. D. Staton, and P. K. Agrawal *In its* Large Space Systems Technol., 1979 Feb. 1980 p 173-185 refs

Avail: NTIS HC A21/MF A01 CSCL 22B

Both deterministic and statistical analysis methods for investigating large aperture antenna radiation patterns are examined. The effects of surface errors on radiation patterns are discussed. M.G.

N80-19166*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
INTERACTIVE ANALYSIS PROGRAM ACTIVITY
J. P. Young, H. P. Frisch, G. K. Jones (Boeing Aerospace Co.), and W. J. Walker *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 383-407

Avail: NTIS HC A21/MF A01 CSCL 22B

The development of an analysis software system capable of performing interdisciplinary preliminary design analyses of large space structure configurations is discussed. Disciplines such as thermal, structures, and controls are to be integrated into a highly user oriented analysis capability. The key feature of the integrated analysis capability, a rapid and efficient system that will minimize solution turnaround time, is discussed. A.W.H.

N80-19167*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

JPL ANALYTICAL PERFORMANCE PREDICTION CAPABILITY

R. Chen *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 409-421

Avail: NTIS HC A21/MF A01 CSCL 22B

The development of a computer code to simulate and predict the performance of large deployable antenna structures is discussed. The computer code is expected to account for all phases of hardware use, i.e., ground handling, boost, deployment, on orbit station keeping, and transfer from LEO to GEO, if applicable. In addition to accounting for static and dynamic loading of the basic structure, the variation in the precision of the reflector surface and the alignment of the feed support structure as a function orbit are scrutinized in order to accommodate electromagnetic analysis. Specific tasks directed towards the development of the computer code are reported and a number of thermal and structural models are discussed. A.W.H.

N80-22736*# Cincinnati Univ., Ohio. Dept. of Aerospace Engineering and Applied Mechanics.

GEOMETRIC MODELING AND ANALYSIS OF LARGE LATTICED SURFACES

Adnan H. Nayfeh and Mohamed S. Hefzy Apr. 1980 65 p refs

(Grant NsG-1185)

(NASA-CR-3156) Avail: NTIS HC A04/MF A01 CSCL 20K

The application of geometrical schemes, similar to geodesic domes, to large spherical antenna reflectors was investigated. The shape and size of flat segmented latticed surfaces which approximate general shells of revolution, and in particular spherical and paraboloidal reflective surfaces, were determined. The extensive mathematical and computational geometric analyses of the reflector resulted in the development of a general purpose computer program capable of generating the complete design parameters of the dish. The program also includes a graphical self contained subroutine for graphic display of the required design. E.D.K.

03
STRUCTURAL CONCEPTS

Includes erectable structures (joints, struts, and columns), deployable platforms and booms, solar sail, deployable reflectors, space fabrication techniques and protrusion processing.

A80-16438 # **Construction of large structures in space.** R. L. Kline (Grumman Aerospace Corp., Bethpage, N.Y.). *American Astronautical Society, Annual Meeting, Los Angeles, Calif., Oct. 29-Nov. 1, 1979, Paper 79-267.* 18 p. 5 refs.

This paper defines five generic categories of space construction ranging from automatic space deployable systems to a fully automated space construction system. Several construction applications are described within these categories which show the significant advance which can be made over our current space capabilities. The necessary steps for bringing these space construction capabilities into practical usage are described. Emphasis is placed on adequate experimental demonstrations to show the user community that they can assimilate the concepts for construction of large structures in space in their future planning. (Author)

A80-20642 * **Structural design of free-flying solar-reflecting satellites.** J. M. Hedgepeth, K. K. Knapp, and L. A. Finley (Astro Research Corp., Carpinteria, Calif.). *Society of Allied Weight Engineers, Annual Conference, 38th, New York, N.Y., May 7-9, 1979, Paper 1303.* 42 p. 11 refs. Contract No. NAS7-100.

A promising spacecraft configuration for utilizing solar radiation is the large flat mirror. Very thin membranes with a reflective coating can be stretched to form such a mirror; the mirror mass density can therefore be very small. The purpose of the presentation is to examine the fundamentals of providing structural support for a free-flying membrane mirror. The objective of the examination is to determine what the masses of the structure might be to support membranes of areas from thousands to millions of square meters operating at altitudes from low-earth orbit to geosynchronous orbit. (Author)

A80-20644 **Weight and performance benefits of space-fabricated composite structures.** L. Browning (General Dynamics Corp., Convair Div., San Diego, Calif.). *Society of Allied Weight Engineers, Annual Conference, 38th, New York, N.Y., May 7-9, 1979, Paper 1310.* 14 p. 8 refs.

An automated on-orbit fabrication technique to produce a continuous triangular beam element of a glass/graphite fiber system in a matrix of thermoplastic resin, with exterior surface coatings, is discussed. Both straight and curved elements of arbitrary length may be generated by programming the beam fabricator's control system. Nominal material storage capacities are based on the production of approximately 900 m of beam used in a baseline planar platform spacecraft, but greater quantities are readily accommodated. To minimize the power drawn from the Shuttle, which will act as the construction base for initial missions, a conservative 80 sec/bay cycle yielding a 2 kW average power requirement is used. The composite beam is characterized by light weight, simplicity, versatility, and compatibility with internal and external component installations. Specific applications include polygonal space frames, planar and contoured surfaces for antennas and solar energy collection, and tribeams for near-term spacecraft and as elements of much larger systems. V.L.

A80-26897 **Considerations in design of large optical structures for space applications using advanced composites.** R. W. Carman (USAF, Rome Air Development Center, Griffiss AFB, N.Y.). In: Advanced composites - Special topics; Proceedings of the Conference, El Segundo, Calif., December 4-6, 1979. El Segundo, Calif., Technology Conferences, 1979, p. 347-369.

Advanced-composite design for the Space Telescope is discussed. The approach to meeting the space application requirements is to replace the solid glass mirror with an assembly consisting of a glass faceplate supported from a graphite/epoxy substrate which contains active actuators to maintain dimensional tolerances. Specifically, Fothergill and Harvey GY70/Code 87 composite laid up in a series of symmetrical angular orientations can be tailored to meet the thermal requirements of a mirror substrate. B.J.

A80-28702 * **Space Platform concepts.** W. C. Snoddy and M. E. Nein (NASA, Marshall Space Flight Center, Huntsville, Ala.). In: Space Shuttle: Dawn of an era; Proceedings of the Twenty-sixth Annual Conference, Los Angeles, Calif., October 29-November 1, 1979. Part 1. San Diego, Calif., American Astronautical Society; Univelt, Inc., 1980, p. 125-153. 5 refs. (AAS 79-264)

Preliminary conceptual approaches for both low earth orbit and geostationary Space Platforms have been developed in response to user requirements. These requirements include payload needs for: operational autonomy, power, size, environmental control (including dynamic, electromagnetic, gaseous, and particulates), on-orbit accessibility, communication and pointing. The concepts developed include both multipurpose and discipline dedicated platforms. In this paper these concepts, their evolution, and their relationship to the needs of the user are presented and discussed. (Author)

A80-31433 **Stabilization of the shape of a surface that is joined together.** V. I. Buiakas. *(Kosmicheskie Issledovaniia,* vol. 17, July-Aug. 1979, p. 547-558.) *Cosmic Research,* vol. 17, no. 4, Jan. 1980, p. 448-459. 5 refs. Translation.

The paper considers the problem of stabilizing the shape of the radio-reflective surface of a large space telescope. It is found that the use of an automatically deploying modular structure makes it possible to control the shape of the reflective surface without elastic deformations of the telescope elements. An iterative method for determining points of reference on the stabilized surface is presented. Control laws are derived for assuring the local stability of module points of reference for structures with sufficiently large focal distances. B.J.

N80-11111*# General Dynamics/Convair, San Diego, Calif.
SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY. (SCAFEDS), PART 3. VOLUME 1: EXECUTIVE SUMMARY Final Report
29 Jun. 1979 33 p
(Contract NAS9-15310)
(NASA-CR-160345; CASD-ASP-78-016-Pt-3-Vol-1) Avail: NTIS HC A03/MF A01 CSCL 22A

A range of tasks focused on a baseline system concept is discussed. A beam builder concept developed to produce a triangular beam is discussed. Beam elements used laminated graphite and glass composite strip material with external surface coatings are described. A.W.H.

N80-13068*# Grumman Aerospace Corp., Bethpage, N.Y.
SPACE FABRICATION DEMONSTRATION SYSTEM. COMPOSITE BEAM CAP FABRICATOR DEVELOPMENT, PHASE 1 AND 2 Final Report
30 Nov. 1979 78 p
(Contract NAS8-32472)
(NASA-CR-161348; NSS-SFDS-RP015) Avail: NTIS HC A05/MF A01 CSCL 22A

Pultrusion as a workable process for thermoset and thermoplastic graphite composite closed caps is discussed. The composite beam fabricator configuration is presented as are the beam cap properties. A.W.H.

N80-16083*# Howard Univ., Washington, D. C. School of Engineering.
STUDY OF FOLDABLE ELASTIC TUBES FOR LARGE SPACE STRUCTURE APPLICATIONS, PHASE 1 Final Report
Irving W. Jones, Collins Boateng, and Caster D. Williams Jan. 1980 58 p refs
(Grant NsG-1320)
(NASA-CR-162652) Avail: NTIS HC A04/MF A01 CSCL 22B

Structural members that might be suitable for strain energy deployable structures, are discussed with emphasis on a thin-walled cylindrical tube with a cross-section that is called 'bi-convex'. The design of bi-convex tube test specimens and their fabrication are described as well as the design and construction of a special purpose testing machine to determine the deployment characteristics. The results of the first series of tests were quite mixed, but clearly revealed that since most of the specimens failed to deploy completely, due to a buckling problem, this type of tube requires some modification in order to be viable. A.R.H.

N80-18301*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
PRELIMINARY DESIGN OF LARGE REFLECTORS WITH FLAT FACETS
Pradeep K. Agrawal, Melvin S. Anderson, and Michael F. Card Jan. 1980 35 p refs
(NASA-TM-80164) Avail: NTIS HC A03/MF A01 CSCL 09C

A concept for approximating curved antenna surfaces using flat facets is discussed. A preliminary design technique for determining the size of the reflector surface facets necessary to meet antenna surface accuracy requirements is presented. A proposed large Microwave Radiometer Satellite is selected as an application, and the far field electromagnetic response of a faceted reflector surface is compared with that from a spherical reflector surface. Author

N80-19144*# McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.
DEVELOPMENT OF A COMPOSITE GEODETIC STRUCTURE FOR SPACE CONSTRUCTION, PHASE 1A
31 Jan. 1980 60 p refs
(Contract NAS9-15678)
(NASA-CR-160558; MDC-G8456) Avail: NTIS HC A04/MF A01 CSCL 22B

The development of a geodetic beam and beam builder for on orbit construction of large truss type space structures is discussed. The geodetic beam is a lightweight, open lattice structure composed of an equilateral gridwork of crisscrossing rods. The beam provides a high degree of stiffness and minimizes structural distortion, due to temperature gradients, through the incorporation of a new graphite and glass reinforced thermoplastic composite material with a low coefficient of thermal expansion. A low power consuming, high production rate, beam builder automatically fabricates the geodetic beams in space using rods preprocessed on Earth. Three areas of the development are focused upon; (1) geodetic beam designs for local attachment of equipment or beam to beam joining in a parallel or crossing configurations, (2) evaluation of long life pultruded rods capable of service temperatures higher than possible with the HMS/P1700 rod material, and (3) evalaution of high temperature joint encapsulant materials. A.W.H.

N80-19146*# Lockheed Missiles and Space Co., Sunnyvale, Calif. Space Systems Div.
OFFSET WEAP RIB CONCEPT AND DEVELOPMENT
A. A. Woods, Jr. *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 5-31

Avail: NTIS HC A21/MF A01 CSCL 22B

The applicability of the Wrap rib antenna design for offset feed configurations for antennas up to 300 m in diameter was assessed. The antenna design was defined for both symmetric and offset configurations in terms of surface quality, cost, weight, and mechanical complexity. A supporting deployable feed support structure was developed and characterized. K.L.

N80-19147*# TRW, Inc., Redondo Beach, Calif.
ADVANCED SUNFLOWER ANTENNA CONCEPT DEVELOPMENT
J. S. Archer *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 33-58 Sponsored by JPL
Avail: NTIS HC A21/MF A01 CSCL 22B

The feasibility of stowing large solid antenna reflectors in the shuttle was demonstrated for applications with 40 foot apertures at frequencies of 100 GHz. Concepts allowing extension of the basic concept to 80-foot apertures operable at 60 GHz were identified. K.L.

N80-19150*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
FY-79 - LSST ANTENNA TECHNOLOGY DEVELOPMENT
Thomas G. Campbell *In its* Large Space Systems Technol., 1979 Feb. 1980 p 95-114

Avail: NTIS HC A21/MF A01 CSCL 22B

The development of technology needed to design, fabricate, transport, and deploy large antenna systems is reported. Accomplishments include: (1) development of scenarios for near term missions in communications, microwave radiometry, and radio astronomy; (2) conceptual designs for critical components of a hoop/column reflector; (3) development of a surface accuracy measurement system; and (4) development of electromagnetic analysis methods for large aperture antennas. K.L.

N80-19151*# Harris Corp., Melbourne, Fla.
DEVELOPMENT OF THE MAYPOLE (HOOP/COLUMN) DEPLOYABLE REFLECTOR CONCEPT FOR LARGE SPACE SYSTEMS APPLICATIONS
D. C. Montgomery and L. D. Sikes *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 115-156 refs
(Contract NAS1-15763)
Avail: NTIS HC A21/MF A01 CSCL 22B

The conceptual design, performance projections, and materials development for the maypole (hoop/column) reflector concept are summarized. Factors influencing configuration choices are discussed along with quad aperture/feed characteristics and antenna requirements based on missions. K.L.

N80-19156*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
STRUCTURAL CONCEPTS FOR LARGE SPACECRAFT
H. G. Bush, W. L. Heard, Jr., and J. E. Walz *In its* Large Space Systems Technol., 1979 Feb. 1980 p 199-215 refs

Avail: NTIS HC A21/MF A01 CSCL 22B

Design concepts for deployable spacecraft structures are examined with particular emphasis on mass/area optimization, stowability, and assembly, and the relations of these requirements to functional design parameters. Component and modular concepts for platforms and reflectors, structural configurations for long columns, pretension columns, and joint concepts are discussed. A brief overview of astronaut and automated assembly studies is included. M.G.

N80-19157*# Vought Corp., Dallas, Tex.
ERECTABLE/DEPLOYABLE CONCEPTS FOR LARGE SPACE SYSTEM TECHNOLOGY
W. E. Agan *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 217-246

(Contract NAS8-33431)
Avail: NTIS HC A21/MF A01 CSCL 22B

Erectable/deployable space structure concepts particularly

relating to the development of a science and applications space platform are presented. Design and operating features for an automatic coupler clevis joint, a side latching detent joint, and a module-to-module auto lock coupler are given. An analysis of the packaging characteristics of stacked subassembly, single fold, hybrid, and double fold concepts is given for various platform structure configurations. Payload carrier systems and assembly techniques are also discussed. M.G.

N80-19158*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
SPACE FABRICATION: GRAPHITE COMPOSITE TRUSS WELDING AND CAP FORMING SUBSYSTEMS
L. M. Jenkins and D. L. Browning (General Dynamics/Convair) *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 247-261 ref

Avail: NTIS HC A21/MF A01 CSCL 22B

An automated beam builder for the fabrication of space structures is described. The beam builder forms a triangular truss 1.3 meters on a side. Flat strips of preconsolidated graphite fiber fabric in a polysulfone matrix are coiled in a storage canister. Heaters raise the material to forming temperature then the structural cap section is formed by a series of rollers. After cooling, cross members and diagonal tension cords are ultrasonically welded in place to complete the truss. The stability of fabricated structures and composite materials is also examined. M.G.

N80-19160*# Rockwell International Corp., Canoga Park, Calif. Satellite Systems Div.
SPACE CONSTRUCTION AND UTILITY DISTRIBUTION
K. A. Bloom *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 287-301

Avail: NTIS HC A21/MF A01 CSCL 22B

Technology advancement to effect an orderly development program leading to construction of space platforms was defined, in a program that utilized a viable platform and service module concept with concise OSS/OAST mission and payload models. Consideration was given to concepts for alternate platform servicing of the payloads described in the model. Using the baseline configuration, issues pertinent to platform development as well as orbit emplacement and operation and on orbit construction methodology were analyzed. These analyses provided the following data: (1) payload definitions and installation options; (2) identified structural and subsystems options; (3) developed integrated platform system concepts; and (4) identified technology deficiencies and recommended technology development timelines. R.C.T.

N80-21394# Contraves Corp., Zurich (Switzerland). Space Dept.
STUDY ON LARGE, ULTRA-LIGHT, LONG-LIFE STRUCTURES IN SPACE: PHASE 1 Final Report
M. C. Bernasconi Jul. 1979 220 p refs
(Contract ESTEC-3445/77-NL-PP(SC))
(ESA-CR(P)-1258) Avail: NTIS HC A10/MF A01

An overview of the concept of large space structures and their possible uses is presented. A large reflector antenna is described and its possible fields of application are summarized. Specifications for the reflector antenna including a performance definition, mission scope, and operational requirements are presented. A number of design concepts for the antenna are analyzed. Among these are a single mesh antenna, a tension wire antenna, and Balloon antenna. Author (ESA)

N80-21624*# TRW Systems Group, Redondo Beach, Calif.
STUDY OF ADVANCED SUNFLOWER PRECISION DEPLOYABLE ANTENNA Final Report
M. M. Giebler and W. B. Palmer 21 Nov. 1979 67 p Prepared for JPL
(Contracts NAS7-100; JPL-955340)
(NASA-CR-162631; MEL-79-B-126) Avail: NTIS HC A04/MF A01 CSCL 09C

The maximum deployed diameter stowable in shuttle was determined for the original concept and for new more efficient concepts. Estimates of weight, surface accuracy and cost were made for the various configurations. Five critical technologies were identified which would be required to manufacture large solid deployable reflectors. These technologies are concerned with surface accuracy improvement and verification. A.R.H.

N80-22735*# Kentron International, Inc., Hampton, Va. Technical Center
A DESIGN PROCEDURE FOR A TENSION-WIRE STIFFENED TRUSS-COLUMN
William H. Greene Apr. 1980 36 p refs
(Contract NAS1-16000)
(NASA-CR-3273) Avail: NTIS HC A03/MF A01 CSCL 20K

A deployable, tension wire stiffened, truss column configuration was considered for space structure applications. An analytical procedure, developed for design of the truss column and exercised in numerical studies, was based on equivalent beam stiffness coefficients in the classical analysis for an initially imperfect beam column. Failure constraints were formulated to be used in a combined weight/strength and nonlinear mathematical programming automated design procedure to determine the minimum mass column for a particular combination of design load and length. Numerical studies gave the mass characteristics of the truss column for broad ranges of load and length. Comparisons of the truss column with a baseline tubular column used a special structural efficiency parameter for this class of columns. E.D.K.

04
CONTROL SYSTEMS

Includes new attitude and control techniques, improved surface accuracy measurement and control techniques.

A80-12730 * # Design of reduced-order controllers for large flexible space structures. S. M. Joshi (Old Dominion University Research Foundation, Norfolk, Va.) and N. J. Groom (NASA, Langley Research Center, Hampton, Va.). In: Annual Allerton Conference on Communication, Control and Computing, 16th, Monticello, Ill., October 4-6, 1978, Proceedings.
Urbana, Ill., University of Illinois, 1978, p. 780-791. 9 refs.

Several approaches to the design of reduced-order controllers for large space structures are discussed. The approaches are based on linear-quadratic-Gaussian (LQG) control theory and include truncation, singular perturbation regulator and estimator, direct sensor feedback, higher-order estimator, and selective suppression of some of the uncontrolled or 'residual' modes. Numerical results are given for a long free-free beam. Sufficient conditions for stability in the presence of control and observation spillovers are outlined. It is shown that the system considered can be satisfactorily controlled using a single torque generator and one attitude and one rate sensor. V.T.

A80-19288 # An adaptive control scheme and its applications to large flexible space structures. Y. W. A. Wu (Martin Marietta Aerospace, Denver, Colo.). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 18th, Pasadena, Calif., Jan. 14-16, 1980, Paper 80-0163.* 9 p. 24 refs.

The paper proposes an adaptive control scheme using the guaranteed error estimation and identification approach as developed by Wu (1978). The method is then applied to a class of large space structures. It is shown that the structural mode frequencies within the system BW can be identified while controlling the system. Finally, simulation studies made for the yaw axis attitude control of a representative large spacecraft are also given. M.E.P.

A80-24226 Joint Automatic Control Conference, Denver, Colo., June 17-21, 1979, Proceedings. Conference sponsored by AIChE, ASME, IEEE, ISA, and SME. New York, American Institute of Chemical Engineers, 1979. 931 p. $110.

Topics are presented on control of large aerospace structures; fine pointing, navigation, tracing and attitude control mechanisms and techniques for satellite systems; further alternatives for linear multivariable control; adaptive control; as well as on asymptotic techniques in flight dynamics and control, and guidance control. Individual subjects include trends in large space control theory, remote infrared imagery of Shuttle during entry, multivariable synthesis with inverses, adaptive feedforward controllers for measurable disturbances, asymptotic continuation method for trajectory optimization, and vortex values for thrust vector and jet interaction control. C.F.W.

A80-24228 * An assessment of methods for the control of large space structures. L. Meirovitch and H. Oz (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Joint Automatic Control Conference, Denver, Colo., June 17-21, 1979, Proceedings. New York, American Institute of Chemical Engineers, 1979, p. 34-41. 32 refs. Contract No. NAS1-15080. NASA Task 6.

Large flexible spacecraft represent highly complex distributed-parameter systems. In theory, a distributed-parameter system possesses an infinite number of degrees of freedom. For practical reasons, however, it must be discretized, which implies truncation. From a structural dynamics point of view, a mathematical model can be made more accurate by retaining an increasing number of degrees of freedom. From a control theory point of view, however, an increasing number of degrees of freedom places severe demands on the reliability of the various control algorithms. There is a difference of at least one order of magnitude between the structural modeling requirements and control theory capability. One of the challenges of large space structures control technology is to bridge this difference. (Author)

A80-24229 Some trends in large space structure control theory: Fondest hopes - Wildest dreams. M. J. Balas (Bolt Beranek and Newman, Inc., Cambridge, Mass.). In: Joint Automatic Control Conference, Denver, Colo., June 17-21, 1979, Proceedings. New York, American Institute of Chemical Engineers, 1979, p. 42-55. 100 refs.

The paper presents a framework for discussing large space structure control theory together with current trends in LSS control theory and related topics in general control science. Attention is given to the mathematical and engineering developments in LSS control, emphasizing various areas of control science that are expected to play a significant role in understanding and solving future LSS control problems. C.F.W.

A80-28020 # Solar pressure three-axis attitude control. B. W. Stuck (Bell Telephone Laboratories, Inc., Murray Hill, N.J.). *Journal of Guidance and Control,* vol. 3, Mar.-Apr. 1980, p. 132-139. 15 refs.

The feasibility of two different designs for a three-axis attitude control system is studied for a synchronous-orbit communication satellite. The attitude control is achieved by torques generated by sunlight striking a set of lightweight reflective surfaces called solar sails. The design is studied via analysis as well as computer simulation of the attitude control dynamics. A nominal trajectory for the satellite attitude is defined, and a set of dynamical equations are derived that are linearized about this nominal trajectory. A sensor scheme is proposed for sensing attitude, and this is combined with the linearized analysis to determine the overall dynamical system behavior for the attitude control system. A sensitivity analysis confirms that the design is robust to unknown disturbance torques and initial conditions far from nominal. (Author)

A80-31657 # Output feedback control of large space structures - An investigation of four design methods. J. G. Lin, D. R. Hegg, Y. H. Lin, and J. E. Keat (Charles Stark Draper Laboratory, Inc., Cambridge, Mass.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 1-18. 18 refs. ARPA-supported research; Contract No. F3062-78-C-0268.

The paper investigates the following design methods for possible application to vibration control of large flexible space structures: (1) output feedback control via modal decoupling (Canavin, 1978), (2) output feedback control by pole assignment (Davison-Wang, 1973), (3) optimal output feedback control (Levine-Athans, 1970), and (4) suboptimal output feedback control (Kosut, 1970). Each of these methods provides a different way of computing constant output feedback gains. The underlying theory, assumptions made, techniques used, computations required, and strengths and weaknesses associated with the various methods are examined. Applicability to vibration control of large space structures with regard to closed-loop performance, stability, and robustness is discussed. Several extensions to the theory, together with concrete suggestions for further research, are reported. Performance comparison of these methods against a common example is made. Significant improvements in performance due to some of the theoretical extensions are demonstrated numerically. (Author)

A80-31658 * # State and model error estimation for distributed parameter systems. G. Rodriguez (California Institute of

Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 19-33. 10 refs. Contract No. NAS7-100.

In-flight estimation of large structure model errors in order to detect inevitable deficiencies in large structure controller/estimator models is discussed. Such an estimation process is particularly applicable in the area of shape control system design required to maintain a prescribed static structural shape and, in addition, suppress dynamic disturbances due to the vehicle vibrational modes. The paper outlines a solution to the problem of static shape estimation where the vehicle shape must be reconstructed from a set of measurements discretely located throughout the structure. The estimation process is based on the principle of least-squares that inherently contains the definition and explicit computation of model error estimates that are optimal in some sense. Consequently, a solution is provided for the problem of estimation of static model errors (e.g., external loads). A generalized formulation applicable to distributed parameters systems is first worked out and then applied to a one-dimensional beam-like structural configuration. (Author)

A80-31659 * # **Controller design approaches for large space structures using LQG control theory.** S. M. Joshi (Old Dominion University, Research Foundation, Norfolk, Va.) and N. J. Groom (NASA, Langley Research Center, Hampton, Va.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 35-50. 12 refs.

The paper presents several approaches for the design of reduced order controllers for large space structures. These approaches are shown to be based on LQG control theory and include truncation, modified truncation regulators and estimators, use of higher order estimators, selective modal suppression, and use of polynomial estimators. Further, the use of direct sensor feedback, as opposed to a state estimator, is investigated for some of these approaches. Finally, numerical results are given for a long free beam. M.E.P.

A80-31661 # **On frequency response interpretations of optimal slewing maneuvers.** K. T. Alfriend, W. S. Bercaw (U.S. Navy, Naval Research Laboratory, Washington, D.C.), and R. W. Longman (Columbia University, New York, N.Y.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 65-76.

In the literature the linear, quadratic, Gaussian optimal control methods have been applied to the problem of maintaining the desired attitude of a flexible spacecraft. In the infinite terminal time case, a frequency response interpretation of the results proved useful in bridging the gap between the classical and optimal results in terms of notch filters. This paper addresses the question of whether the frequency response point of view can be similarly useful in interpreting the optimal controls for slewing of flexible spacecraft. Although frequency response interpretations are found to be of more limited value in the slewing maneuver case, they are found to be useful in generating possible simple implementations of the optimal controls. (Author)

A80-31665 * # **A procedure for optimal control of flexible surface vibrations.** A. K. Caglayan, H. F. VanLandingham, and S. G. Sathe (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 129-144. 20 refs. Grant No. NsG-1527.

The vibration controller design for a thin flexible surface with a given boundary is formulated as an unconstrained optimization problem. It is shown that this formulation is equivalent to a system of uncoupled optimization problems each of which is a linear regulator design problem for a second-order modal system. The regulator solutions give the gains on the modal amplitude and velocity associated with each modal system. For the constrained control case corresponding to a finite number of actuators, an approximation to the optimal distributed control is given. For the case of a limited number of physical sensors, a dual approach yields a system of second-order observers or filters. Simulations indicate that the constrained controller has a satisfactory performance as long as the number of actuators is more than half the number of controlled modes. (Author)

A80-31666 * # **On the controllability of a long flexible beam in orbit.** P. M. Bainum and A. S. S. R. Reddy (Howard University, Washington, D.C.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 145-159. 9 refs. Grant No. NsG-1414.

The equations of planar motion for a long, flexible free-free beam in orbit are developed and include the effects of gravity-gradient torques and control torques resulting from actuators assumed to be located at specific points along the beam. The control devices are used to control both the orientation as well as the shape of the beam. Application of two classes of theorems to the linearized form of these equations is used to establish necessary and sufficient conditions for controllability for different combinations of number/location of actuators with the number of modes contained in the mathematical model. It is seen that the number of actuators, if properly located, can be less than the number of modes in the system model. A numerical example illustrates the controlled response to an initial perturbation in both pitch angle as well as beam shape. (Author)

A80-31668 # **Simulation of a digital controller for flexible spacecraft attitude control.** Y. Ohkami, O. Okamoto, and T. Kida (National Aerospace Laboratory, Tokyo, Japan). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 177-192. 8 refs.

Attitude control schemes for a class of flexible spacecraft are implemented on a breadboard model of a programmable digital controller using a microprocessor. Included in the schemes are a classical compensator via the root locus method and a state variable feedback compensator with or without observers. The flexible spacecraft attitude dynamics and the other parts of a control system (e.g. sensors and actuators) are simulated by a minicomputer to which the digital controller is connected through digital-to-analog and analog-to-digital converters. The schemes are compared with respect to performance and complexity of the program. The results obtained from the simulation runs provide information on the validity, advantages and limitations of the programmable controller, and will be useful for selecting and evaluating a control scheme to be used in onboard digital processors. (Author)

A80-31672 * # **Formulations and applications of large structure actuator and sensor placements.** J.-N. Juang and G. Rodriguez (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 247-262. 8 refs. Contract No. NAS7-100.

A new approach based on the steady-state solutions of the optimal control and estimation problems is presented to study respectively the actuator and sensor locations for large flexible structures. A simple and computer-implementable formulation for

minimizing the steady state optimal cost function and the state estimation error inherent in the estimation process is given. In conjunction with the new approach, two criteria are established relating the actuator and the sensor placement optimalities respectively to the minimums of the optimal cost function and the state estimation error. To illustrate the concepts of this paper, we present the results of some numerical and analytical studies on the actuator and the sensor locations of several simple flexible beam modes.
(Author)

A80-31673 # **Spacecraft identification through Kalman filtering.** D. A. Johnson (Louvain, Université Catholique, Louvain-la-Neuve, Belgium). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 263-277. 7 refs. European Space Agency Contracts No. 2163/74; No. 3320/77.

The extended Kalman filtering algorithm has been used for the simultaneous state estimation and parameter identification of a geostationary satellite modelled as a central rigid body with two articulated rigid booms. Dynamics simulation tests with up to five parameters exhibited good convergence to the real values. The set of the most important parameters comprised of the two inertia ratios, which decide on the spacecraft attitude stability, products of independent components of the main body inertia I13 and I23, and z-coordinate of the mass center were defined and the algorithm with these parameters was substantiated by actual in-flight measurement data. A comparison between the technique designed and the sequential decision technique showed that the first produced a higher final accuracy when the uncertainty on the parameters was smaller than the latter. A completely operational and flexible computer program is available. O.L.

A80-31676 * # **Approaches to adaptive digital control focusing on the second order modal descriptions of large, flexible spacecraft dynamics.** C. R. Johnson, Jr. (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979.
Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 301-315. 54 refs. Research supported by the Engineering Foundation; Grant No. NsG-1527.

The widespread modal analysis of flexible spacecraft and recognition of the poor a priori parameterization possible of the modal descriptions of individual structures have prompted the consideration of adaptive modal control strategies for distributed parameter systems. The current major approaches to computationally efficient adaptive digital control useful in these endeavors are explained in an original, lucid manner using modal second order structure dynamics for algorithm explication. Difficulties in extending these lumped-parameter techniques to distributed-parameter system expansion control are cited. (Author)

A80-31682 # **Actuator number versus parameter sensitivity in flexible spacecraft control.** D. C. Kammer and J. R. Sesak (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979.
Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 421-441. 22 refs.

The parametric sensitivity problem for spacecraft control is considered and some interesting (and unexpected) results concerning actuator number and insensitivity to parameter variations are reported. Simulation results presented demonstrate that for the class of systems considered, an increase in the number of actuators tends to decrease the sensitivity of the closed-loop system to parameter variations. Thus, the designer has at his disposal a result which provides a new rationale for increasing the dimensions of the control vector. This new result has ramifications for spacecraft control as the number of actuators employed is under the designer's control; i.e., the dimension of the input (or influence) matrix for the distributed system is not fixed as it is for a lumped system. The analytical explanations for these robust results are presented using return difference magnitudes and Perkins and Cruz's comparison sensitivity criterion. One particular example is presented wherein the addition of a single actuator results in an increased tolerance to parameter variations of one order of magnitude. (Author)

A80-31683 # **Closed loop order reduction for large structures control.** R. Gran and M. Rossi (Grumman Aerospace Corp., Bethpage, N.Y.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 443-457. 7 refs.

The paper deals with a low-order model used in the design of control systems for large distributed structures. An iterative order reduction procedure is described. As a criterion for reducing the dimension of the model, the performance index used for optimal control design is evaluated for suboptimal control gain that results from the order reduction. V.T.

A80-31685 * # **On truncated expansion self-tuning regulation of a large AMCD.** A. L. Hamm, J. S. Tsui, and C. R. Johnson, Jr. (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 475-486. Grant No. NsG-1527.

The one-dimensional wave equation models out of plane displacement of a flexible ring and with appropriate boundary conditions the solution is one of uncoupled modes. Identification and control of the behavior of these modes by means of a self-tuning regulator requires precise measurements of the ring shape. Aliasing of modes occurs from a finite number of sensors along the ring causing interference in the modal identification. Nonuniform sensors spacing allows for reduced aliasing effects but introduces spreading of the modes and provides inconsistent measurements. The homogeneous wave equation solution for modal time behavior aids in the separation of the aliasing effects, but difficulty arises when the ring is spinning past the sensors and control forces are being applied.
(Author)

A80-31686 # **Commutativity of inversion and truncation operations in modal analysis for flexible large spacecraft.** Y. Ohkami (National Aerospace Laboratory, Tokyo, Japan). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979.
Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 487-494.

It is noted that for efficient numerical simulations of flexible space structures, truncation operations are essential. A condition was developed for the commutativity of inversion and truncation operations, but was found to be too stringent to apply to most actual problems. A less restrictive condition for the commutativity is presented. It is shown to be based on the comparison of vector norms associated with truncated and retained portions of a matrix consisting of eigenvectors provided by finite element modal analysis. In addition, the established condition gives a mathematical rationale to engineering practices. M.E.P.

A80-31690 # **Parameter plane analysis for large flexible spacecraft.** B. A. Asner, Jr. (Dallas, University, Irving, Tex.) and S. M. Seltzer (Control Dynamics Co., Huntsville, Ala.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979.
Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 545-560. 7 refs.

The parameter plane technique for stability analysis has been modified to obviate the sometimes cumbersome (particularly for

high order systems) derivation of the characteristic equation. Instead, it is proposed to implement this technique by manipulating the matrices of the original system equations. The objective is to keep the concepts simple and leave the tedious tasks to the computer. The proposed alternate technique is described and then applied to two examples. (Author)

A80-31696 * # Flexible space structure model reduction by modal cost analysis. R. E. Skelton (Purdue University, West Lafayette, Ind.) and P. C. Hughes (Toronto, University, Toronto, Canada). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 641-660. 13 refs. Contract No. JPL-955369.

It is noted that reduced models and reduced controllers for flexible space structures are obtained by retaining those modes which make the greatest contribution to quadratic control objectives. Attention is given to the relative importance of damping, frequency and mode shapes in the mode truncation decisions for the following control objectives: attitude control, vibration suppression and figure control. It is also shown that using Modal Cost Analysis (MCA) on the closed loop modes of the optimally controlled system allows the construction of reduced control policies which feedback only those closed loop coordinates which are most critical to the quadratic control performance criterion. In this manner, the modes which need to be controlled are deduced from truncations of the optimal controller. M.E.P.

A80-31697 # Application of modern modal controller design to a large space structure. R. R. Strunce and T. C. Henderson (Charles Stark Draper Laboratory, Inc., Cambridge, Mass.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 661-675. 10 refs. ARPA-supported research; Contract No. F30602-78-C-0268.

This paper presents a design methodology for active vibration suppression in a large space structure based on Canavin's member damper concept and Bala's modern modal controller. The structure is augmented by member dampers which are configured to increase the structure's inherent damping. This structural damping augmentation is sufficient to offset observation spillover and control spillover; hence, overall system stability is achievable. A modern modal controller is designed to control the critical modes which impact line-of-sight performance. The resulting control law is shown to be robust with respect to broad parameter variations of the structure. (Author)

A80-31699 # Modal-space control of large flexible spacecraft possessing ignorable coordinates. L. Meirovitch and H. Oz (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979, p. 701-727. 18 refs.

An independent modal-space scheme for the control of positional, attitude and elastic motions of a distributed-parameter flexible spacecraft with ignorable coordinates is presented. The scheme consists of a first-level control designed to restrain the ignorable coordinates associated with the rigid body motions and a second-level control designed to control the full state of the augmented spacecraft. The dual-level modal space control is implemented by using several types of control laws; proportional control providing artificial viscous damping, proportional optimal control, and nonlinear on-off control are discussed. A numerical example of a flexible dual-spin spacecraft with a locked rotor is presented. J.P.B.

A80-32109 Guidance and Control Mini-Symposium, Reading, Mass., March 14, 1980, Technical Papers. Symposium sponsored by the American Institute of Aeronautics and Astronautics. New York, American Institute of Aeronautics and Astronautics, Inc., 1980. 105 p.

Studies presented on this guidance and control mini-symposium include control and observation spillover reduction in vibration control of large flexible structures, gravity standards for inertial component testing, and performance of an aided redundant navigator in normal and failure modes. Among the other works are active control of certain flexible systems using distributed and boundary control and a combined optimal/classical approach to robust missile autopilot design. V.T.

A80-32110 # Reduction of control and observation spillover in vibration control of large flexible space structures. J. G. Lin (Charles Stark Draper Laboratory, Inc., Cambridge, Mass.). *(American Institute for Aeronautics and Astronautics, Guidance and Control Conference, Boulder, Colo., Aug. 6-8, 1979, Paper 79-1763.)* In: Guidance and Control Mini-Symposium, Reading, Mass., March 14, 1980, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1980, p. 14-21. 7 refs. Contract No. F30602-78-C-0268.

The methods by which boundary control can be incorporated into interior control of current truncated modal control systems are discussed along with the resulting combined system structure. A different approach to boundary control, namely, nonreflective boundary control, is defined. A scheme is proposed in which the nonreflective boundary control is implemented by a simple output feedback along with a reduced-order truncated modal system. V.T.

N80-15201*# Old Dominion Univ. Research Foundation, Norfolk, Va.

CONTROL SYSTEMS DESIGN FOR LARGE FLEXIBLE SPACE STRUCTURES Final Report, 15 Nov. 1977 - 14 Jan. 1980

Suresh M. Joshi and A. S. Roberts, Jr. (Old Dominion Univ.) Jan. 1980 21 p refs

(Grant NsG-1473)

(NASA-CR-162582) Avail: NTIS HC A02/MF A01 CSCL 22B

Several approaches for the design of reduced-order linear-quadratic-Gaussian type controllers for large space structures were proposed and evaluated using a continuous model of a long free-free beam. Sufficient conditions were derived for the asymptotic stability with this type of controller. A finite-element model of a free-free-free-free square plate was obtained for use in control systems studies. A method was developed for optimal damping enhancement in large space structures. Author

N80-16082*# Grumman Aircraft Engineering Corp., Bethpage, N. Y. Research Dept.

CONTROL OF LARGE SPACE STRUCTURES Final Report

R. Gran, M. Rossi, H. G. Moyer, and F. Austin Apr. 1979 134 p refs

(Contract NAS8-32587)

(NASA-CR-161369; RE-589) Avail: NTIS HC A07/MF A01 CSCL 22B

The control of large space structures was studied to determine what, if any, limitations are imposed on the size of spacecraft which may be controlled using current control system design technology. Using a typical structure in the 35 to 70 meter size category, a control system design that used actuators that are currently available was designed. The amount of control power required to maintain the vehicle in a stabilized gravity gradient pointing orientation that also damped various structural motions was determined. The moment of inertia and mass properties of this structure were varied to verify that stability and performance were maintained. The study concludes that the structure's size is required to change by at least a factor of two before any stability problems arise. The stability margin that is lost is due to the scaling of the gravity gradient torques (the rigid body control) and as such can easily be corrected by changing the control gains associated with the rigid body control. A secondary conclusion from the study is that the control design that accommodates the structural motions (to damp them) is a little

more sensitive than the design that works on attitude control of the rigid body only. R.E.S.

N80-18768*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Electrical Engineering.
THE REDUCED ORDER MODEL PROBLEM IN DISTRIBUTED PARAMETER SYSTEMS ADAPTIVE IDENTIFICATION AND CONTROL Interim Report
C. Richard Johnson, Jr. Mar. 1980 76 p refs
(Grant NAG-1-7)
(NASA-CR-162807) Avail: NTIS HC A05/MF A01 CSCL 09B

The research concerning the reduced order model problem in distributed parameter systems is reported. The adaptive control strategy was chosen for investigation in the annular momentum control device. It is noted, that if there is no observation spill over, and no model errors, an indirect adaptive control strategy can be globally stable. Recent publications concerning adaptive control are included. F.O.S.

N80-19148*# Lockheed Missiles and Space Co., Sunnyvale, Calif.
CONSTRUCTION ALIGNMENT SENSOR FEASIBILITY DEMONSTRATIONS (LASER MEASUREMENT)
R. H. Anderson *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 59-76

(Contract NAS7-100; JPL-955130)
Avail: NTIS HC A21/MF A01 CSCL 22B

The design theory and trade-offs involved in the selection of laser heterodyne sensors for use in active control of spacecraft structures are discussed. These sensors include a HeNe distance measuring system for structures requiring accuracies to .1 mm, a CO2 distance measuring system for measuring unambiuously down to .01 microns, and vibration sensors based on both HeNe and CO2 lasers. K.L.

N80-19149*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
JPL SELF PULSED LASER SURFACE MEASUREMENT SYSTEM DEVELOPMENT
Martin Berdahl *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 77-94

Avail: NTIS HC A21/MF A01 CSCL 22B

The use of a self pulsed laser system for accurately describing the surface shape of large space deployed antenna structures was evaluated. Tests with a breadboard system verified functional operation with short time resolution on the order of .2 mm, nonambiguous ranging, and a maximum range capability on the order of 150 m. The projected capability of the system is resolution of less than .1 mm over a reasonable time period and a range extension to over 300 m. K.L.

N80-19162*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
LARGE SPACE SYSTEM CONTROL TECHNOLOGY OVERVIEW
Gary L. Parker *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 313-321

Avail: NTIS HC A21/MF A01 CSCL 22B

The nature of the problems which confront large space structure technology controls are discussed. Emphasis is placed on the following: the basic performance requirements; structural model errors; the effect of certain disturbances (i.e., solar pressure, gravity gradient torques, and aerodynamic drag); and surface or figure control. R.C.T.

N80-19163*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
LARGE SPACE SYSTEM CONTROL TECHNOLOGY STATUS AND ACCOMPLISHMENTS
G. Rodriguez and Gary L. Parker *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 323-342 refs
Avail: NTIS HC A21/MF A01 CSCL 22B

In the area of antenna modeling and control, preliminary structural models were defined for two representative parabolic reflectors. A control system design evolved for attitude control of the reflectors. The controller design was based on a lumped control concept where the control hardware (sensor and actuators) was mounted at the base of the antenna. In the area of distributed control, static shape control techniques were worked out to establish a prescribed vehicle shape. The corresponding estimation process for determination of vehicle shape from selected sensor measurements was also developed. A model order reduction study was conducted to find the best preflight dynamical models for on board controller design. The problems caused by truncation of the vehicle dynamics required to minimize on board computations were investigated. Estimator designs were developed for on board detection of large structure model errors. R.C.T.

N80-19164*# Purdue Univ., Lafayette, Ind.
LARGE SPACE SYSTEM CONTROL TECHNOLOGY MODEL ORDER REDUCTION STUDY
R. E. Skelton *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 343-357 Sponsored by JPL
Avail: NTIS HC A21/MF A01 CSCL 22B

The mission control requirements for large space structures are presented as well as some of the problems associated with the active control of large structures in space. A generic model is introduced that contains most of the desired features in the modeling and control problem for large space structures. R.C.T.

N80-19165*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
LaRC CONTROLS ACTIVITY FOR LSST
R. C. Montgomery *In its* Large Space Systems Technol., 1979 Feb. 1980 p 359-381

Avail: NTIS HC A21/MF A01 CSCL 22B

Math models were developed for various types of large flexible structures These models were used to study the uncontrolled dynamic characteristics of the structures in orbit and to devise control concepts in order to control their orientation and geometrical shape. Reduced order decoupled control of the 100 meter long free free beam were studied. The inplane orientation and shape of the beam was controlled in a decoupled manner with as few actuators as possible. Using two controllers, near each end of the beam, to produce a 0.01 radian pitch change, perfect decoupled control was achieved for the rigid body pitch theta mode and the first flexible mode A sub 1. R.C.T.

05
ELECTRONICS

Includes techniques for power and data distribution.

N80-19168*# Boeing Aerospace Co., Seattle, Wash.
LARGE SPACE SYSTEMS TECHNOLOGY ELECTRONICS: DATA AND POWER DISTRIBUTION
W. G. Dunbar *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 423-442

(Contract NAS8-33432)
Avail: NTIS HC A21/MF A01 CSCL 22B

The development of hardware technology and manufacturing techniques required to meet space platform and antenna system needs in the 1980s is discussed. Preliminary designs for manned and automatically assembled space power system cables, connectors, and grounding and bonding materials and techniques are reviewed. Connector concepts, grounding design requirements, and bonding requirements are discussed. The problem of particulate debris contamination for large structure spacecraft is addressed. A.W.H.

N80-19170*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
FY-79 - DEVELOPMENT OF FIBER OPTICS CONNECTOR TECHNOLOGY FOR LARGE SPACE SYSTEMS
Thomas G. Campbell *In its* Large Space Systems Technol., 1979 Feb. 1980 p 453-466

Avail: NTIS HC A21/MF A01 CSCL 22B

The development of physical concepts for integrating fiber optic connectors and cables with structural concepts proposed for the LSST is discussed. Emphasis is placed on remote connections using integrated cables. A.W.H.

06
ADVANCED MATERIALS

Includes matrix composites, polyimide films and thermal control coatings, and space environmental effects on these materials.

A80-10206 # Design and operation of multi-specimen fully reversed fatigue systems for advanced composite materials. G. Waring, K. E. Hofer, Jr., I. Brown (IIT Research Institute, Chicago, Ill.), and R. E. Trabocco (U.S. Naval Material Command, Naval Air Development Center, Warminster, Pa.). *Society for Experimental Stress Analysis, Spring Meeting, San Francisco, Calif., May 20-25, 1979, Paper.* 34 p. 24 refs. Navy-supported research.

Advanced composite materials are finding extensive utilization in aerospace structural applications. The composites appear usually as the skins (surfacing elements) on sandwich components. The paper describes an experimental system designed to investigate the static compressive strengths of graphite/epoxy composite sandwich structures with various defects, after exposure to combined moisture-saturation and elevated temperature environment in the presence of fatigue stress cycling of the variable amplitude type in a fully reversed mode. The objective of this program was to establish the degradation modes in sandwich construction as it applies to naval aircraft. The feasibility of testing several samples simultaneously in a simulated aerospace environment is clearly demonstrated by the results to date. Removal of blistered and cracked sealant revealed some evidence of aluminum honeycomb corrosion products, the corrosion being of general, not galvanic, nature. S.D.

A80-10210 * # The effects of thermal cycling on the thermal deformation of graphite-polyimide. M. W. Hyer and J. A. Hagaman (Old Dominion University, Norfolk, Va.). *Society for Experimental Stress Analysis, Spring Meeting, San Francisco, Calif., May 20-25, 1979, Paper.* 48 p. Grant No. NsG-1167.

The effects of repetitive thermal cycling on the thermal deformation of graphite-fiber-reinforced polyimide laminates are investigated. Unsymmetric and unidirectional laminate specimens were cycled in an oven between room temperature and 180 or 315 C five times, and temperature and deformation were recorded as a function of time in order to measure thermal deformation. The results of the lower temperature cycling reveal a hysteresis-like effect in the temperature-thermal deformation relation for a single cycle, while no differences are detected from one cycle to the next. The response of an eight-layer curved specimen is found to agree well with predictions based on a piecewise-linear lamination theory, however, four-layer laminate response could not be explained. The results of the high-temperature tests also indicate a dependence of the strain on whether the specimen was being heated or cooled, however quantitative results are considered unreliable, due to strain gage difficulties. A.L.W.

A80-11326 Adhesive bonding in satellite applications. R. L. Long (Rockwell International Corp., Satellite Systems Div., Downey, Calif.). In: Structural adhesives and bonding; Proceedings of the Conference, El Segundo, Calif., March 13-15, 1979. El Segundo, Calif., Technology Conferences Associates, 1979, p. 360-381.

Satellites containing optical systems have an additional environmental concern that is unique. These satellites cannot tolerate the formation and deposition of any contaminant that will settle on, and thereby reduce the performance of the optical devices. Adhesive bonding in satellite applications is discussed relative to environments, service requirements, and adherends. The characteristics of film and paste adhesives are described. It is shown that adhesive bonding is an invaluable method for assembling unmanned spacecraft. The requirement for the use of low volatile condensible producing materials to prevent the degradation of optics has resulted in the utilization of more brittle adhesives. Also, satellites do not require the same concerns over moisture intrusion and corrosion as do conventional aircraft. S.D.

A80-11327 Polyimide adhesives for the Space Shuttle. A. A. Stenersen (Rockwell International Corp., Shuttle Orbiter Div., Downey, Calif.). In: Structural adhesives and bonding; Proceedings of the Conference, El Segundo, Calif., March 13-15, 1979. El Segundo, Calif., Technology Conferences Associates, 1979, p. 382-395. 10 refs.

The paper presents the results of a preliminary evaluation study of a variety of polyimide adhesive formulations for bonding Space Shuttle components of titanium and graphite-polyimide composites. Topics covered include the processing of resin and prepreg, adherend surface preparation and priming, and staging and bonding of film adhesive. Test results given cover the evaluation of scrim materials, the effect of staging on lap shear strength, and comparison of addition-type polyimide adhesives. It is concluded that several addition-type polyimide adhesives satisfy the Shuttle requirements in processability, ability to form large-area, void-free bonds and in bond strengths. In addition, it is shown that the condensation-type polyimide adhesives evaluated lack the ability to form void-free, large-area bonds. M.E.P.

A80-11345 Aircraft designers follow the birds. M. Hewish. *New Scientist,* vol. 84, Oct. 4, 1979, p. 33-35.

Advanced, lightweight, flexible composite materials and metal joining techniques for future aircraft structures are presented. Advanced composites are shown to require fewer parts to form a structure and less enery to produce than structural metals, in addition to being stronger, stiffer and more corrosion resistant. The fabrication of carbon- and boron-fiber-reinforced plastics is examined and examples of applications of carbon-fiber composites in British fighter aircraft and boron-fiber composites in U.S. bombers and fighters including those of the Air Force/NASA-sponsored Highly Maneuverable Aircraft Technology program are presented. Boron-fiber-reinforced aluminum and boron/carbon/glass fiber epoxy composites and other promising fiber-matrix combinations are indicated, and complementary developments in the powder casting of aluminum, aluminum-lithium alloys and titanium aircraft structures are outlined. Results of the U.S. Air Force Primarily Adhesively Bonded Structure Technology program are presented and the use of new materials for space structures is considered. A.L.W.

A80-15967 The radiation environment and its effects on spacecraft. J. Janni and G. Radke (USAF, Weapons Laboratory, Kirtland AFB, N. Mex.). In: Quantitative modeling of magnetospheric processes. Washington, D.C., American Geophysical Union, 1979, p. 634-643.

A parametric study has been performed to evaluate the effects of different electron and proton spectral shapes on the dose deposited behind realistic satellite shielding. The high energy component above 1-MeV of geomagnetically trapped electrons is not well known, introducing a considerable uncertainty in shield design. Only recently has emphasis been placed on accurately measuring the spectrum of electrons above 1-MeV. However, these are the electrons that produce most of the dose within typical electronics subsystems. Lower energy electrons usually do not penetrate the shielding provided by satellite structure and electronics housings. The sensitivity of the dose has been parametrically evaluated for electron spectra having moderately different high energy components. This evaluation has been performed for simple spherical shields and for the actual shielding provided by an operational USAF satellite. Moderate changes in shielding can provide drastic reductions in the accumulated electron dose. The inner radiation zone contains protons with very high energies that extend well beyond 30-MeV. The shielding provided by most contemporary satellites is insufficient to stop these protons. Unlike the situation for electrons, it is very difficult to easily shield these protons. (Author)

A80-19317 * # **Material problems in solar sail development.** W. H. Steurer. *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 18th, Pasadena, Calif., Jan. 14-16, 1980, Paper 80-0315.* 10 p. 10 refs. Contract No. NAS7-100.

The paper considers the solar sail principle as an effective means of space propulsion. The heliogyro configuration is discussed including the hub structures, the flap-hinge brace assembly, and the blade. The material requirements of the sail film made of metallized polymers, the tendons produced from a polymer-graphite fiber composite, and battens constructed of graphite/epoxy tubings are considered, noting that not all of these materials were readily available. It was concluded that the primary material problems are the environmental degradation of polymer films, the meteoroid hazard, and the production capacity for large polymer film quantities. A.T.

A80-21127 **Composites for aerospace applications.** S. J. Dastin (Grumman Aerospace Corp., Bethpage, N.Y.). In: Composite materials: Testing and design; Proceedings of the Fifth Conference, New Orleans, La., March 20-22, 1978. Philadelphia, Pa., American Society for Testing and Materials, 1979, p. 5-13. 5 refs.

A review of composites for aerospace applications is presented. Advanced composites have been established as a primary structural material for aerospace applications, and large volume applications for graphite and aramid fibers are forecast. Current U.S. military aircraft, such as F-14, F-15, and F-16, utilize composites for empennage components, and future commercial aircraft will use these materials to reduce weight and save fuel. Composites were utilized to fabricate the payload bay doors for the Space Shuttle Orbiter, and composite tubular structures of near-zero thermal coefficient were used for the large space telescope; other aircraft areas being evaluated for composite application are floor beams, decks, and engine components. A.T.

A80-26898 **Advanced composites considerations in design of large space antennas.** M. R. Sullivan and B. E. McIntosh (Harris Corp., Melbourne, Fla.). In: Advanced composites - Special topics; Proceedings of the Conference, El Segundo, Calif., December 4-6, 1979. El Segundo, Calif., Technology Conferences, 1979, p. 370-403. 6 refs.

This paper discusses the application of advanced composites in the design of large space deployable antennas. Graphite-epoxy composites are the dominate structural materials utilized in existing designs. The benefits and short comings of graphite-epoxy are discussed. Metal Matrix Composites (MMC) are presented as potential rival materials to graphite-epoxy in future antenna designs requiring larger and more accurate reflectors. The properties of MMC and graphite epoxy are compared, and potential antenna performance improvements discussed. (Author)

A80-27987 # **Experimental characterization of the yield surface of metal-matrix composite material.** M. F. Duggan (Synergistic Technology, Inc., Cupertino, Calif.). In: Modern developments in composite materials and structures; Proceedings of the Winter Annual Meeting, New York, N.Y., December 2-7, 1979. New York, American Society of Mechanical Engineers, 1979, p. 109-121.

A new biaxial test technique is proposed for the mechanical behavior analysis of metal-matrix composites. Under particular loading conditions the biaxial test technique provides an inplane shear test. It is shown that the inplane shear yield strength resulting from the proposed test is a more accurate value than that obtained from the 10 degree off-axis shear test. Data on graphite/aluminum verify the predictions of the Hoffman continuum model for metal-matrix composites. V.L.

N80-11226*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ELECTRON AND PROTON ABSORPTION CALCULATIONS FOR A GRAPHITE/EPOXY COMPOSITE MODEL
Edward R. Long, Jr. Nov. 1979 33 p refs
(NASA-TP-1568; L-13073) Avail: NTIS HC A02/MF A01 CSCL 11G

The Bethe-Bloch stopping power relations for inelastic collisions were used to determine the absorption of electron and proton energy in cured neat epoxy resin and the absorption of electron energy in a graphite/epoxy composite. Absorption of electron energy due to bremsstrahlung was determined. Electron energies from 0.2 to 4.0 MeV and proton energies from 0.3 to 1.75 MeV were used. Monoenergetic electron energy absorption profiles for models of pure graphite, cured neat epoxy resin, and graphite/epoxy composites are reported. A relation is determined for depth of uniform energy absorption in a composite as a function of fiber volume fraction and initial electron energy. Monoenergetic proton energy absorption profiles are reported for the neat resin model. A relation for total proton penetration in the epoxy resin as a function of initial proton energy is determined. Electron energy absorption in the composite due to bremsstrahlung is reported. Electron and proton energy absorption profiles in cured neat epoxy resin are reported for environments approximating geosynchronous earth orbit. R.C.T.

N80-14187# European Space Research and Technology Center, Noordwijk (Netherlands). Product Assurance Div.
GUIDELINES FOR SPACE MATERIALS SELECTION
Paris ESA Jul. 1979 120 p refs
(ESA-PSS-07/QRM-01-Issue-5) Avail: NTIS HC A06/MF A01

The different classes of materials used in spacecraft manufacture are reviewed, their chemical nature and physical aspects are described, and processing and assembly methods are considered. Precautions to be taken and materials to be avoided are emphasized for each class. General effects of the space environment are also described. Some individual materials which are suitable for space application under certain conditions are mentioned. Author (ESA)

N80-16117*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
TRENDS IN MATERIALS' OUTGASSING TECHNOLOGY
Joe A. Colony Nov. 1979 27 p
(NASA-TM-80585) Avail: NTIS HC A03/MF A01 CSCL 07D

Test sample acquisition and chemical analysis techniques for outgassing products from spacecraft, experiment modules, and support equipment is described. The reduction of test data to a computer compatible format to implement materials selection policies is described. A list of the most troublesome outgassing species is given and several materials correlations are discussed. Outgassing from solar panels, thermal blankets, and wire insulation are examined individually. M.G.

N80-19171*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
FLEXIBLE MATERIALS TECHNOLOGY
W. H. Steurer *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 467-484

Avail: NTIS HC A21/MF A01 CSCL 22B

A survey of all presently defined or proposed large space systems indicated an ever increasing demand for flexible components and materials, primarily as a result of the widening disparity between the stowage space of launch vehicles and the size of advanced systems. Typical flexible components and material requirements were identified on the basis of recurrence and/or functional commonality. This was followed by the evaluation of candidate materials and the search for material capabilities which promise to satisfy the postulated requirements. Particular attention was placed on thin films, and on the requirements of deployable antennas. The assessment of the performance of specific materials was based primarily on the failure mode, derived from a detailed failure analysis. In view of extensive on going work on thermal and environmental degradation effects, prime emphasis was placed on the assessment of the performance loss by meteoroid damage. Quantitative data were generated

for tension members and antenna reflector materials. A methodology was developed for the representation of the overall materials performance as related to systems service life. A number of promising new concepts for flexible materials were identified.
Author

N80-19172*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
ADVANCED MATERIALS FOR SPACE
Darrel R. Tenney, Wayne S. Slemp, Edward R. Long, Jr., and George F. Sykes *In its* Large Space Systems Technol., 1979 Feb. 1980 p 485-504

Avail: NTIS HC A21/MF A01 CSCL 22B
The principal thrust of the LSST program is to develop the materials technology required for confident design of large space systems such as antennas and platforms. Areas of research in the FY-79 program include evaluation of polysulfones, measurement of the coefficient of thermal expansion of low expansion composite laminates, thermal cycling effects, and cable technology. The development of new long thermal control coatings and adhesives for use in space is discussed. The determination of radiation damage mechanisms of resin matrix composites and the formulation of new polymer matrices that are inherently more stable in the space environment are examined. Author

N80-20325*# National Bureau of Standards, Washington, D.C. National Measurement Lab.
ADVANCED COMPOSITES: DESIGN AND APPLICATION. PROCEEDINGS OF THE MEETING OF THE MECHANICAL FAILURES PREVENTION GROUP Final Report
T. Robert Shives and William A. Willard Oct. 1979 307 p refs Conf. held at Gaithersburg, Md., 23-25 May 1979 Sponsored in part by ONR, Arlington, Va., Naval Air Systems Command, Washington D.C., NASA Goddard Space Flight Center., and DOE, Washington, D.C.
(NASA-CR-162864; PB80-105109; NBS-SP-563; LC-79-600151) Avail: NTIS HC A14/MF A01 CSCL 11D
The design and application of advanced composites is discussed with emphasis on aerospace, aircraft, automotive, marine, and industrial applications. Failure modes in advanced composites are also discussed. GRA

N80-21420# European Space Agency, Paris (France).
SPACECRAFT MATERIALS IN SPACE ENVIRONMENT
J. Dauphin, ed. and T. D. Guyenne, ed. Dec. 1979 338 p refs Proceedings of ESA Symp., Noordwijk, Netherlands, 2-5 Oct. 1979
(ESA-SP-145) Avail: NTIS HC A15/MF A01
The state-of-the-art in the field of Spacelab materials was discussed in the context of analysis methods, new materials developments, cleanliness and contamination (practice and theory), materials in various project types, radiation and electrostatic charge effects, and specific applications.

N80-21423# Technochemie G.m.b.H., Dossenheim (West Germany). Verfahrenstechnik.
THERMAL ANALYTICAL METHODS FOR CHARACTERIZATION OF RESINS, PREPREGS AND COMPOSITES
H. Stenzenberger and M. Herzog *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 23-34 refs

(Contract ESTEC-2930/76-NL-PP(SC))
Avail: NTIS HC A15/MF A01
The differential scanning calorimetry (DSC) characteristics of seven model epoxy resin curing agent combinations is presented. In addition, the DSC cure behavior of a typical autoclave grade high temperature bismaleimide resin is evaluated. The calculation of cure cycles based on DSC data and time-temperature profiles of a commerical autoclave are demonstrated for two epoxy resins and a polyimide resin material. For a new high temperature epoxy resin formulation based on TGDDM and m-Aminobenzoic acid hydrazide, it is demonstrated that differential scanning calorimetry can be used to define the state of advancement of the resin and therefore to control the quality of carbon fiber unidirectional prepregs. Thermal mechanical analysis techniques are used to develop postcure cycles. Author (ESA)

N80-21424# Air Force Materials Lab., Wright-Patterson AFB, Ohio. Coatings and Thermal Protection Materials Branch.
NEW SPACE MATERIALS DEVELOPMENTS IN THE UNITED STATES
W. L. Lehn *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 37-47 refs

Avail: NTIS HC A15/MF A01
The development and evaluation of transparent conductive coatings, conductive bulk materials and grounding techniques for application to high resistivity dielectric spacecraft materials to eliminate or control spacecraft charging are discussed. Techniques for the application of thin transparent conductive indium oxide, indium/tin oxide and other metal oxide coatings to Kapton, FEP Teflon, OSR and solar cell coverglasses are presented. The development of conductive bulk glass and stable low outgassing fabric type thermal control coatings as spacecraft charging control materials is presented. Author (ESA)

N80-21425# Atomic Energy Research Establishment, Harwell (England). Materials Development Div.
ADVANCED CARBON FIBER COMPOSITES FOR SPACECRAFT USE
D. H. Bowen *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 49-62 refs

Avail: NTIS HC A15/MF A01
Basic methods for the preparation of carbon fibers are presented and the relationship between fiber properties and structure is described. Carbon fiber composites with carbon, metal and resin matrices are briefly reviewed and examples of applications for resin composites in spacecraft are described. The possible course of future developments is also discussed.
Author (ESA)

N80-21426# Centre National de la Recherche Scientifique, Toulouse (France).
PAINTS, POTTING COMPOUNDS AND SILICONE VARNISHES WITH LOW OUTGASSING IN SPACE ENVIRONMENT **c27**
J. C. Guillaumon and J. Guillin *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 63-66 refs

Avail: NTIS HC A15/MF A01
A purifying process was used to produce paints, potting compounds and varnishes with low outgassing under vacuum. Paints were made from purified silicon - coated binders showing a good stability under U. V. irradiations. The thermo-optical and outgassing properties of these paints were studied. Environment tests (thermal cycling, moisture resistance and U. V. irradiations) were also carried out. Silicone products usable as adhesives for bonding filters on solar cells, potting compounds for electronic modules, mastics and isolation varnishes, etc., were obtained by the same purifying process. Mechanical, optical, and outgassing properties were also studied. Author (ESA)

N80-21433# Centre National de la Recherche Scientifique, Toulouse (France).
EVALUATION OF KINETIC OUTGASSING UNDER VACUUM FOR POTTING COMPOUNDS AND PAINTS
J. Guillin *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 139-144 refs

Avail: NTIS HC A15/MF A01
The evaluation of contamination in space by use of a computer model is discussed in terms of kinetic outgassing of materials under vacuum. The weight loss under vacuum for potting compounds and thermal coating furnished by the manufacturer

or purified in the laboratory was measured by 'micro-VCM' tests carried out at different temperatures and for periods as long as 2000 h. From these tests, equations of outgassing rates depending on time and temperature are proposed. It is shown that the Arrhenius equation is applicable for any temperature within the range studied and therefore it is possible to obtain 'activation energies' for the total outgassing of these materials. The effects of the purifying process and of the polymerization parameters (time, temperature) on outgassing energy and time dependance are also described. Author (ESA)

N80-21439# European Space Research and Technology Center, Noordwijk (Netherlands).
ELECTROSTATIC CHARGING AND SPACE MATERIALS

J. Bosma and F. Levadou *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 189-207 refs

Avail: NTIS HC A15/MF A01

The relevance of electrostatic cleanliness aspects of materials is addressed. There has been extensive progress in the study of the effects of electrostatic charging in thermal control coatings, and from the materials points of view electrostatic cleanliness can be implemented in a cost effective manner on future spacecraft projects. The materials are discussed on the basis of experimental data obtained in-house or under ESA contract. A survey of the on-going activities in several major European laboratories on electrostatic charging is presented. Author (ESA)

N80-21442# Centre d'Etudes et de Recherches en Technologie Spatiale, Toulouse (France). Dept. d'Etudes et de Recherches en Technologie Spatiale.
EFFECT OF RADIATIONS ON POLYMERS AND THERMAL CONTROL COATINGS
J. Bourrieau and A. Paillous *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 227-245 refs

(Contracts ESTEC-2015/74; ESTEC-2558/75; ESTEC-2515/75; ESTEC-2838/76; ESTEC-3184/77; ERNO-102010/A/37880)
Avail: NTIS HC A15/MF A01

A survey of the problem encountered with polymers and thermal control coatings submitted to radiations in space is presented. A theoretical study that models the degradation of the solar absorptance under electron and proton irradiations is described. The model takes the absorbed energy dose repartition within the material into account and assumes that the solar absorptance variation is inputed to color centers, the concentration of which can be expressed in terms of dose. The relevance of such a correlation is corroborated by measurements performed on two polymers and two white paints. An example of a radiation qualification test program carried out for OTS is given. Predicted degradations of the thermal control coatings are compared to data obtained after one year in orbit. Author (ESA)

N80-21443# Lockheed Missiles and Space Co., Palo Alto, Calif.
RANGE AND INTERACTION OF LOW ENERGY PROTONS IN METAL AND METAL OXIDE THERMAL CONTROL MATERIALS
S. A. Greenberg and M. McCargo *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 247-254 refs

Avail: NTIS HC A15/MF A01

The effects of low energy protons on the properties of typical metal and metal oxide thermal control materials are addressed from a fundamental mechanistic standpoint. A direct method for evaluating range energy relationship for protons in a variety of stopping media is described. Comparison of the results for metals of diverse atmospheric numbers has led to modification of existing range theory incorporating corrected electronic stopping cross sections. A phenomenological model for the proton induced coloration of zinc oxide pigments was formulated. Experimental results indicate that optically active defect centers are created which do not undergo self annihilation even at very high levels of proton bombardment. Author (ESA)

N80-21444*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
AN ANALYTICAL APPROACH TO EVALUATION OF SPACE RADIATION EFFECTS ON MATERIALS FOR LONG-LIFE MISSIONS
J. Moacanin, A. Gupta, and W. F. Carroll *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 255-261 refs

(Contract NAS7-100)
Avail: NTIS HC A15/MF A01 CSCL 22B

An analytical model was developed which quantifies effects on organic composite matrix materials of high energy electrons and of UV as well as interactions between the two radiations. Literature data on polyethylene were used to construct a degradation kinetics scheme corresponding to an Earth orbit at L=3. Analysis of the model showed that steady state concentrations of radicals put limits on accelerated test conditions. These conclusions were validated by an experimental study on polymethylmethacrylate using UV laser excitation. Relationships for balancing electron and UV radiations to equal acceleration factors are derived. Pulse radiolysis using an electron-beam along with time-resolved spectroscopy is shown to be able to separate primary form secondary reactions. Implications of these reactions to changes in engineering material properties are indicated. The use of mechanistic studies is discussed in the context of general test strategies for evaluating materials for space applications. Author (ESA)

N80-21445# Toronto Univ. (Ontario). Inst. for Aerospace Studies.
SPACE ENVIRONMENTAL EFFECTS ON POLYMER MATRIX COMPONENTS
R. C. Tennyson, J. S. Hansen, B. Uffen, D. Morison, and G. Mabson *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 263-271 refs

(Grants AFFOSR-3694-78; NRC-A-2783)
Avail: NTIS HC A15/MF A01

Long and short term behavior of fiber reinforced polymer matrix composite materials subjected in a simulated space environment were investigated. Emphasis was placed on the influence of thermal vacuum conditions on mechanical stiffness (E22), strength (sigma 2 U) and coefficient of thermal expansion (CTE). One important feature of these all tests involving the vacuum environment was made in situ, thus eliminating the possibility of specimen contamination by reaction with the atmosphere (moisture reabsorption). CTE data were exceeding six months duration. The resulting information will be useful in the design of spacecraft structures fabricated from this class of composite materials. Author (ESA)

N80-21447# Societe Nationale Industrielle Aerospatiale, Les Mureaux (France). Space and Ballistic Systems Div.
USE OF ULTRA-LIGHT ADHESIVE FOR THE METAL HONEYCOMB BONDING
J. Chanteranne *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 287-291

Avail: NTIS HC A15/MF A01

The design of satellite panels in sandwich structures must be optimized in order to reduce the mass, by fitting the strength of the bonding menisci to the strength of the honeycomb core. This optimization applied to the satellite structures of the Intelsat V family has led to the use of an adhesive of very low surface mass (100 g/m2), which is unusual for the bonding of honeycomb. Manufacturing experience is described for such structures with adhesive films and the influence of the hygrometry of the bonding room, and of the use of a primer on the geometry and strength of the adhesive menisci formed on the honeycomb. Author (ESA)

07
ASSEMBLY CONCEPTS

Includes automated manipulator techniques, EVA, robot assembly, teleoperators, and equipment installation.

A80-15266 # **/Hard Hat/ EVA, personal equipment to support large scale construction in space.** R. C. Wilde (United Technologies Corp., Hamilton Standard Div., Windsor Locks, Conn.). *American Society of Mechanical Engineers, Intersociety Conference on Environmental Systems, 9th, San Francisco, Calif., July 16-19, 1979, Paper 79-ENAs-43.* 9 p. Members, $1.50; nonmembers, $3.00.

During the next 20 years, extravehicular activity (EVA) to assemble large-scale space structures in orbit will require equipment with high cycle life, high mobility joints and improved hygiene for use up to 8 hours during both orbital light and dark periods, at pressures up to 0.54 Atm (to eliminate the purge oxygen pre-breathe). The pressure enclosure will feature no don-doff assistance, wrist-mounted displays and controls, the movable scye bearing (to allow overhead arm movement), and modular construction for comfort. The materials evaluated for up to 29 kg of radiation shielding are metallic glass, multidrawn Chromel-R metal fabric and flexible laminated sheet material. The transmissibility of wide angle helmet visors will be automatically controlled by miniature photo sensors, while there is a novel concept of thermal insulation for the gloves. The potassium carbonate liquid sorbent process (regenerable) may replace lithium hydroxide (non-regenerable) as a carbon dioxide remover in the life support system, and thermal control will be effected by a hybrid concept: a sublimator/phase change material, radiator approach. J.P.B.

A80-23977 # **Future manned machines and operations in space.** J. R. Tewell, R. A. Spencer, J. A. Lenda, and J. W. Mooney (Martin Marietta Aerospace, Denver, Colo.). In: World Congress on the Theory of Machines and Mechanisms, 5th, Montreal, Canada, July 8-13, 1979, Proceedings. Volume 1. New York, American Society of Mechanical Engineers, 1979, p. 78-81.

Construction of large systems in space will require unique, complex, and diverse support equipment, some automated and others involving manned operations. This paper presents an overview of the support equipment to be used for orbital assembly of large structures. Conceptual designs and system definitions for each element are discussed. Examples include free-flying teleoperators, manipulative systems with lengths exceeding 50 m, structure-attached material and personnel transporters with an operating range of several kilometers, and a manned remote work station analogous to the present-day ground-based 'cherrypicker'. The descriptive material provided includes equipment conceptual designs, operational considerations, and overall applications. (Author)

A80-23993 # **System design features of the Space Shuttle remote manipulator.** P. Kumar, P. Truss, and C. G. Wagner-Bartak (Spar Aerospace, Ltd., Toronto, Canada). In: World Congress on the Theory of Machines and Mechanisms, 5th, Montreal, Canada, July 8-13, 1979, Proceedings. Volume 1. New York, American Society of Mechanical Engineers, 1979, p. 839-842. 7 refs.

The Space Shuttle Remote Manipulator (RMS) is an anthropomorphic, man-machine system primarily used for deploying and retrieving payloads (satellites, space modules) in orbit. The manipulator arm features a modularized design approach and the use of similar or common components. The data transfer between the various RMS interfaces is handled using a system of digital data busses. The system has been made 'instinctive' by the use of an appropriate control hierarchy which enables the astronaut/operator to simply move the manipulator end point without controlling the individual joints. Safety requirements have been met by incorporateing a back-up system to the principal control modes and a built-in scheme of fault detection and annunciation. The RMS is presently scheduled to be integrated into the orbital flight test program in 1979. (Author)

A80-23996 # **Recursive solution to the equations of motion of an N-link manipulator.** W. W. Armstrong (Montréal, Université, Montreal, Canada). In: World Congress on the Theory of Machines and Mechanisms, 5th, Montreal, Canada, July 8-13, 1979, Proceedings. Volume 2. New York, American Society of Mechanical Engineers, 1979, p. 1343-1346.

The equations of motion of a manipulator formed by a sequence of N rigid links, joined to each other and to a spacecraft or a terrestrial base by hinges which allow up to three rotational degrees of freedom, are solved by a recursive technique which does not involve operations on matrices larger than 3x3. This technique, which has also been generalized to the case of flexible links, has been programmed on a CYBER 173 computer for the development of the Shuttle Remote Manipulator System. (Author)

N80-11779# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
LINEAR STATE FEEDBACK CONTROL OF RIGID-LINK MANIPULATORS
David F. Golla May 1979 66 p refs
(UTIAS-TN-214; ISSN-0082-5263) Avail: NTIS HC A04/MF A01

Linear state variable feedback controllers were designed for rigid-link manipulator arms. Two types of feedback schemes were considered, general rigid control (GRC) which allows for both interjoint and intrajoint feedback, and independent joint control (IJC) which allows for only intrajoint feedback. The design scheme consisted of arbitrary closed loop pole placement. Pole assignment algorithms were developed for both GRC and IJC feedback control schemes. Two controllers, IJC and GRC, were designed for a preliminary two-link rigid model of the space shuttle manipulator arm carrying a full payload in planar motion. The two models are simulated and the controllers compared. R.E.S.

N80-13063*# Rockwell International Corp., Canoga Park, Calif.
SPACE CONSTRUCTION SYSTEM ANALYSIS, FINAL REVIEW. PART 1: EXECUTIVE SUMMARY
1979 50 p
(Contract NAS9-15718)
(NASA-CR-160286; PD79-18) Avail: NTIS HC A03/MF A01 CSCL 22A

Several large space system projects which would drive out specific requirements for space construction are considered. A data base was developed to provide designers of large systems with convenient systematic access to methods of space construction and associated requirements. The results obtained were applied to technologies other than the study project. M.M.M.

N80-17709*# Grumman Aerospace Corp., Bethpage, N.Y.
MANNED REMOTE WORK STATION DEVELOPMENT ARTICLE. VOLUME 1, BOOK 1: FLIGHT ARTICLE REQUIREMENTS. APPENDIX A: MISSION REQUIREMENTS Final Report
1 Mar. 1979 317 p
(Contract NAS9-15507)
(NASA-CR-160463; NSS-MR-RP008-Vol-1-Book-1) Avail: NTIS HC A14/MF A01 CSCL 05H

The requirements for several configurations of flight articles are presented. These requirements provide the basis to design manned remote work station development test articles and establish tests and simulation objectives for the resolution of development issues. Mission system and subsystem requirements for four MRWS configurations included: open cherry picker; closed cherry picker; crane turret; and free flyer. R.C.T.

N80-17710*# Grumman Aerospace Corp., Bethpage, N.Y.
MANNED REMOTE WORK STATION DEVELOPMENT

ARTICLE. VOLUME 1, BOOK 2, APPENDIX B: TRADE AND DESIGN DEFINITION STUDIES Final Report
1 Mar. 1979 201 p
(Contract NAS9-15507)
(NASA-CR-160464; NSS-MR-RP008-Vol-1-Book-2) Avail: NTIS HC A10/MF A01 CSCL 05H

System trades, evaluations, and selection were organized under the appropriate manned remote work station roles and subsystems. Those trades/evaluations that have an impact on simulator fidelity were given emphasis in terms of identifying alternate concepts, making a selection, and defining the system approach. Those trades that do not impact simulator fidelity have the issues delineated and future study requirements identified.
R.C.T.

N80-17711*# Grumman Aerospace Corp., Bethpage, N.Y.
MANNED REMOTE WORK STATION DEVELOPMENT ARTICLE. VOLUME 2: SIMULATION REQUIREMENTS. APPENDIX A: OPEN CHERRY PICKER DEVELOPMENT TEST ARTICLES SPECIFICATION Final Report
1 Mar. 1979 132 p
(Contract NAS9-15507)
(NASA-CR-160465; NSS-MR-RP008-Vol-2) Avail: NTIS HC A07/MF A01 CSCL 05H

A manned remote work station (MRWS) mission scenario, broken down into the three time phases was selected as the basis for analysis of the MRWS flight article requirements and concepts. The mission roles for the three time phases, supporting tradeoff and evaluation studies, was used to identify key issues requiring simulation. The MRWS is discussed in terms of its capability to perform such operations as support of Spacelab experiments, servicing and repair of satellites, and construction. Future considerations for the use of the MRWS are also given.
R.C.T.

N80-17712*# Grumman Aerospace Corp., Bethpage, N.Y.
MANNED REMOTE WORK STATION DEVELOPMENT ARTICLE. VOLUME 3: DEVELOPMENT TEST PLAN. APPENDIX A: MANUFACTURING REQUIREMENTS/ SCHEDULE Final Report
1 Mar. 1979 180 p
(Contract NAS9-15507)
(NASA-CR-160466; NSS-MR-RP008-Vol-3) Avail: NTIS HC A09/MF A01 CSCL 05H

The tests and procedures for the manned remote work station (MRWS) open cherry picker (OCP) development test article (DTA) are described to validate systems requirements and performance specifications. A development test program is outlined to evaluate key design issues and man/machine interfaces when the MRWS OCP is used in a shuttle support role of satellite servicing and in orbit construction of large structures. R.C.T.

N80-19159*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
STRUCTURAL ASSEMBLY IN SPACE
Jack W. Stokes and Edwin C. Pruett (Essex Corp.) *In* NASA. Langley Res. Center Large Space Systems Technol., 1979 Feb. 1980 p 263-285 refs

Avail: NTIS HC A21/MF A01 CSCL 22B

A cost algorithm for predicting assembly costs for large space structures is given. Assembly scenarios are summarized which describe the erection, deployment, and fabrication tasks for five large space structures. The major activities that impact total costs for structure assembly from launch through deployment and assembly to scientific instrument installation and checkout are described. Individual cost elements such as assembly fixtures, handrails, or remote minipulators are also presented.
R.C.T.

08
PROPULSION

Includes propulsion designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts.

A80-10376 * # Characteristics of primary electric propulsion systems. D. C. Byers (NASA, Lewis Research Center, Electric Thruster Section, Cleveland, Ohio). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2041.* 13 p. 21 refs.

The use of advanced electric propulsion systems will provide cost and performance benefits for future energetic space missions. A methodology to predict the characteristics of advanced electric propulsion systems was developed and programmed for computer calculations to allow evaluation of a broad set of technology and mission assumptions. The impact on overall thrust system characteristics was assessed for variations of propellant type, total accelerating voltage, thruster area, specific impulse, and power system approach. The data may be used both to provide direction to technology emphasis and allow for preliminary estimates of electric propulsion system properties for a wide variety of application. (Author)

A80-10378 # RIT 35 - Design and application of the Giessen primary propulsion engine. K. H. Groh, P. Abel, E. Rumpf, and H. W. Loeb (Giessen, Universität, Giessen, West Germany). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2053.* 9 p. 12 refs.

The paper surveys the design and development of radio-frequency ion thrusters (RIT) at Giessen University. The RIT 35 engine is covered, noting its differences with the RIT 10 which involve three essential points: a central tube, a common vaporizer, and a metal plasma holder. Topics also covered include preliminary performance data, transfer missions with RIT 35, solar generator degradation, and spiralling up from circular orbit, as well as from elliptical orbit. Computer calculations are cited which show the applicability of the large ion thruster for transfer missions resulting in a significant payload gain compared with chemical propulsion. It is concluded that once electric propulsion has been introduced into space applications ion motors of the RIT 35 type have a good chance of realization. M.E.P.

A80-10380 * # Plasma processes in inert gas thrusters. H. R. Kaufman and R. S. Robinson (Colorado State University, Fort Collins, Colo.). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2055.* 14 p. 24 refs. Grant No. NsG-3011.

Inert gas thrusters, particularly with large diameters, have continued to be of interest for space propulsion applications. Two plasma processes are treated in this study: electron diffusion across magnetic fields and double ion production in inert-gas thrusters. A model is developed to describe electron diffusion across a magnetic field that is driven by both density and potential gradients, with Bohm diffusion used to predict the diffusion rate. This model has applications to conduction across magnetic fields inside a discharge chamber, as well as through a magnetic baffle region used to isolate a hollow cathode from the main chamber. A theory for double ion production is presented, which is not as complete as the electron diffusion theory described, but it should be a useful tool for predicting double ion sputter erosion. Correlations are developed that may be used, without experimental data, to predict double ion densities for the design of new and especially larger ion thrusters. S.D.

A80-10389 # MPD arcjet system for space experiment with particle accelerator /SEPAC/. K. Ijichi, H. Harada (Mitsubishi Electric Corp., Kamakura, Kanagawa, Japan), and K. Kuriki (Tokyo, University, Tokyo, Japan). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2072.* 9 p.

The paper describes the MPD arcjet system design and reports the results of the qualification tests. Attention is given to the two functions which the MPD system performs: (1) to eject plasma into the ambient atmosphere in order to study the characteristics of plasma propagation, and (2) to neutralize the charge build-up on the Shuttle caused by the electron beam ejection. Safety tests covered include: destruction test of a capacitor with the capacitor bank, destruction test with a large charging current, and chemical endurance of O-ring material. Qualification tests covered include electrical performance test, mechanical environment test, and thermal vacuum test. Finally, attention is given to design changes which should be made. M.E.P.

A80-10391 * # Preliminary results of the mission profile life test of a 30 cm Hg bombardment thruster. R. T. Bechtel (NASA, Lewis Research Center, Solar Electric Propulsion Office, Cleveland, Ohio) and E. L. James (Xerox Electro-Optical Systems, Pasadena, Calif.). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2078.* 14 p. 14 refs.

The paper deals with some preliminary results of the Mission Profile Life Test planned to conduct a program of long-term test segments of 30-cm diameter thrusters and power processing units under computer control. Thruster performance data and other operational characteristics taken at various times during a test segment are compared and the results are evaluated in light of the life-timing mechanisms. Thruster control algorithms are also presented. The first test segment completed 2700 hr of a planned 4000 hr test with a J-series 30-cm thruster. The last 1600 hr used a functional model power processing unit (PPU) operated in vacuum. The thruster-PPU was controlled by a computer with software developed to control start-ups, throttling, and variety of off-normal conditions. V.T.

A80-10394 * # Solar array technology for solar electric propulsion missions. L. E. Young (NASA, Marshall Space Flight Center, Huntsville, Ala.). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2086.* 6 p. 6 refs.

Development of 66 W/kg and 200 W/kg solar arrays for solar electric propulsion is discussed along with two basic concentrator solar array design concepts. Considerable testing was performed to demonstrate the availability and capability of the technology used for these arrays. To provide complete demonstration of 66 W/kg technology, a full-scale wing was built and tested and NASA decided to fly it as an experiment on one of the early Shuttle flights. Performance of the concentrator array system was demonstrated by model testing in a thermal-vacuum chamber. V.T.

A80-10395 * # Solar array technology developments and design for electric propulsion application. E. N. Costogue and W. A. Hasbach (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2087.* 6 p. Contract No. NAS7-100.

The design, fabrication, and test of foldout and rollout multikilowatt solar array models are discussed. Consideration is given to the development of (1) thin 50-micron solar cells; (2) laminated Kapton plus substrates; (3) thin 50 to 100-micron coverglass; (4) low-mass structure designs; (5) low-mass blanket designs; and (6) solar insolation concentrators to enhance solar array performance. It is noted that the recent achievements in solar cell technology have shown that blanket specific power of 120 W/kg and higher is realizable for solar arrays, thus meeting propulsion stage requirements. V.T.

A80-10396 * # **Nuclear power source for electric propulsion.** J. F. Mondt, G. Stapfer, and T. Hsieh (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2088.* 9 p. Contract No. NAS7-100.

A low specific weight (20 to 40 Kg/Kwe), long life (6 to 10 year), 100 to 400 KWe nuclear electric propulsion (NEP) system can deliver 2,000 to 10,000 Kg payloads for intensive study of our solar system. The nuclear power source is about 80% of the NEP system mass, thus the NASA program is focused on developing the power source technology. Because of the long life requirements, direct thermal to electric energy conversion technology (thermionic and thermoelectric) is being pursued. In order to meet the low specific weight it is necessary to develop a 10 to 15% conversion module with a 875 K minimum heat rejection temperature and a 1675 K maximum input temperature. The thermoionic converter is about 9% efficient at these temperatures. The thermoelectric converter is limited to a 1300 K input temperature. So, the thermionic program is focused on improving the efficiency while the thermoelectric program is focused on increasing the temperature. (Author)

A80-10397 # **100-kWe nuclear space electric power source.** D. Buden (California, University, Los Alamos, N. Mex.). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2089.* 8 p.

A 100-kWe space nuclear power technology program which could provide an electric power source for nuclear electric propulsion is analyzed. The power plant includes a reactor, radiation shield protecting payload, a converter producing electricity from thermal energy of the reactor, and radiator discharging waste heat. The reactor consists of a central core section surrounded by a neutron reflector and control region. The core consists of UO2 fuel and layers of molybdenum sheets to transfer the thermal energy to heat pipes. The reflector is made of BeO and divided into segments. The plant has a weight of 1775 kg, a length of around 7 m, a lifetime of 7 years with a reliability of 0.95, and meets Shuttle volume constraints. Emphasis is placed on key results of the component experimental program including core heat pipe, core fastener, heat transfer, critical assembly, and thermoelectric module studies. V.T.

A80-10398 # **Electric rail gun application to space propulsion.** J. P. Barber (International Applied Physics, Inc., Dayton, Ohio). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2091.* 7 p. 7 refs.

The paper examines the possibility of using the DC electric gun principles as a space vehicle propulsion system, capable of producing intermediate thrust levels. The application of an electromagnetic launch technique, called the DC electric rail gun, to the space propulsion concept of O'Neill, is examined. It is determined that the DC electric rail gun offers very high projectile accelerations and a very significant potential for reducing the size and mass of a reaction motor for space application. A detailed description of rail gun principles is given and some simple expressions for the accelerating force, gun impedance, power supply requirements, and system performance are discussed. C.F.W.

A80-10403 # **Inert gas radio-frequency thruster RIT 10.** K. H. Groh, O. Blum, H. Rado, and H. W. Loeb (Giessen, Universität, Giessen, West Germany). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2100.* 10 p. 10 refs.

It is noted that the use of mercury as a propellant may restrict the application of the electric propulsion system due to the poisonousness and/or availability of mercury. The present paper describes the RIT 10 engine modified to operate with xenon and argon. Attention is given to the modified design, function tests and performance mapping for the ion thruster and the plasma bridge neutralizer. The experiments show that the thruster works well with both gases, noting that the data for xenon are similar to that of mercury, but preliminary tests demonstrate lower efficiencies for argon than with xenon. In conclusion, it is proven that no fundamental problems exist in operating the ion thruster with argon. M.E.P.

A80-10405 * # **Interactions between a spacecraft and an ion thruster produced environment.** M. R. Carruth, Jr. and E. V. Pawlik (California Institute of Technology, Jet Propulsion Laboratory, Electrical Power and Propulsion Section, Pasadena, Calif.). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2107.* 10 p. 23 refs.

A model of the charge-exchange plasma flow around a spacecraft is used to determine charge-exchange plasma densities and arrival rates at various locations on the spacecraft. A general assessment of particle deposition and effects of such are presented as they relate to the spacecraft and particular science instruments. Various aspects of the interactions between the ion thruster produced environment and a Comet Rendezvous (CR) spacecraft are addressed. No instruments will be affected adversely when the thrusters are off, excluding those that have passive radiators which may collect mercury. V.T.

A80-10409 * # **NASA electric propulsion program.** W. R. Hudson (NASA, Electric Propulsion Branch, Washington, D.C.). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2118.* 9 p. 14 refs.

The NASA Electric Propulsion technology program is focused at three major specific objectives - to develop the Baseline Solar Electric Propulsion (SEP) technology for interplanetary transportation applications; to develop ion thruster technology for auxiliary propulsion applications; and to research fundamental processes and advanced concepts. This paper will discuss accomplishments since the last Electric Propulsion Conference, the current status of the program, and future directions. (Author)

A80-10410 * # **Solar electric propulsion system /SEPS/ program plans and system definition.** R. E. Austin (NASA, Marshall Space Flight Center, Huntsville, Ala.) and W. A. Kisko (NASA, Washington, D.C.). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2119.* 4 p.

The status of the NASA Solar Electric Propulsion System (SEPS) program is reviewed. The plans for SEPS definition and development include the initiation of the SEPS definition phase, the procurement for full-scale development in 1980, delivery of the SEPS for integration and tests with the comet rendezvous spacecraft in 1984, and a launch in 1985 that involves a flyby of Halley's comet in 1985 and a subsequent rendezvous with the comet Tempel 2 in 1988. In preparation for this, the acquisition process for SEPS has been initiated based on mission requirements rather than system requirements. V.T.

A80-10411 # **European electric propulsion activities.** H. W. Loeb, J. Freisinger, K. H. Groh (Giessen, Universität, Giessen, West Germany), H. Bassner (Messerschmitt-Bölkow-Blohm GmbH, Munich, West Germany), R. Buehler (Stuttgart, Universität, Stuttgart, West Germany), W. U. Klein (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Cologne, West Germany), G. Krulle (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Stuttgart, West Germany), V. Naso (Roma, Università, Rome, Italy), H. O. Ruppe (München, Universität, Munich, West Germany), and H. Pfeffer (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands). *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2120.* 16 p. 37 refs.

At present, the German RF-thrust assembly RITA is the only West European electric propulsion system subjected to a space qualification program and scheduled definitely to be flown. The major other European electric propulsion program is that sponsored by the ESTEC center of the European Space Agency on field emission electric propulsion (FEEP), a concept in which ions are produced by electric field emission. Consideration is given to other R & D activities at some universities, e.g. at Rome (continuation of plasma efforts), Stuttgart (plasma and field emission work), Munich (mission analysis), and Giessen (primary propulsion, spacecraft charging, terrestrial applications, and physics). Positional control of commercial satellites is still the primary goal in Europe. However, along with the progress in ARIANE launcher completion, some interest increases in primary propulsion for payload increment. V.T.

A80-12149 # **Ion thruster plasma dynamics near high voltage surfaces on spacecraft.** H. B. Liemohn, D. H. Holze, W. M. Leavens, and R. L. Copeland (Boeing Aerospace Co., Seattle, Wash.) *Princeton University, AIAA, and DGLR, International Electric Propulsion Conference, 14th, Princeton, N.J., Oct. 30-Nov. 1, 1979, AIAA Paper 79-2105*. 7 p. 15 refs.

Ion thrusters are being considered for propulsion of future spacecraft due to their high propulsion efficiency and easy access to solar power for long-duration missions. Operation of such thrusters requires high spacecraft potentials, and their local electric fields can draw return current from the thruster plasmas, reducing system efficiency. In this paper, the thruster plasma is assumed to be described by a collimated energetic beam (about 10 keV) and a cloud of ionized thermal propellant (about 10 eV) produced by charge exchange. A simple adiabatic model is used to describe the expansion of these neutral plasmas away from the source. As the pressure falls, shielding currents dissipate, and the geomagnetic field takes control of the particles. Results appropriate to proposed electric propulsion missions and the solar power satellite are presented, and operational considerations are discussed. (Author)

A80-16447 * # **SEPS mission and system integration/interface requirements for the space transportation system.** M. J. Cork, P. M. Barnett, J. Shaffer, Jr. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.), and B. J. Doran (NASA, Marshall Space Flight Center, Systems Laboratory, Huntsville, Ala.). *American Astronautical Society, Annual Meeting, Los Angeles, Calif., Oct. 29-Nov. 1, 1979, Paper 79-287*. 17 p. Contract No. NAS7-100.

Earth escape mission requirements on Solar Electric Propulsion System (SEPS), and the interface definition and planned integration between SEPS, user spacecraft, and other elements of the STS. Emphasis is placed on the Comet rendezvous mission, scheduled to be the first SEPS user. Interactive SEPS interface characteristics with spacecraft and mission, as well as the multiple organizations and inter-related development schedules required to integrate the SEPS with spacecraft and STS, require early attention to definition of interfaces in order to assure a successful path to the first SEPS launch in July 1985. (Author)

A80-21227 # **What large-scale use of ion engines would do to the magnetosphere and ionosphere.** Y. T. Chiu, J. G. Luhmann, B. K. Ching, M. Schulz, and D. J. Boucher, Jr. (Aerospace Corp., El Segundo, Calif.). *Astronautics and Aeronautics*, vol. 18, Feb. 1980, p. 46, 47, 62.

It is noted that some form of plasma-beam engine appears most likely to be the primary candidate for space transportation of the future due to the desire to keep to a minimum the mass of propellant for making the orbital change. As an example the paper investigates the effects of ionospheric and magnetospheric modification by ion-engine exhausts for orbit transfer of the Solar Power Satellite. It is shown that the total number of argon ions injected into the ionosphere and plasmasphere during a single nominal large-scale space mission would roughly equal the total ion content of the magnetosphere, whereas the total particle energy injected would be 10-100 times that of the natural magnetosphere. Attention is given to the effects of such increases on humans, communications and earth sensors. M.E.P.

A80-26303 **The use of ion thrusters for orbit raising.** D. G. Fearn (Royal Aircraft Establishment, Farnborough, Hants., England). *British Interplanetary Society, Journal (Space Technology)*, vol. 33, Apr. 1980, p. 129-137. 27 refs.

Earlier analytical results for changing the orbital altitude of a spacecraft, using a tangentially thrusting electric propulsion system, have been employed to confirm that the mass of propellant required to attain a geostationary orbit is only a very small fraction of the initial mass of the satellite. Such an orbit transfer technique requires a relatively long period of time compared with chemical propulsion, typically 100 to 300 days, and, for spacecraft masses of 1000 kg or more, multi-kW solar arrays are necessary. The long transfer time also leads to a significant degradation of the power produced by these solar arrays, due to the impact on them of energetic particles while traversing the earth's radiation belts. Nevertheless, it is concluded that this technique for maneuvering a satellite into synchronous orbit can offer attractive economic benefits for satellites of 1000 kg or less, for which a dedicated ion thruster system can be advocated, and for much larger devices, for which a reusable solar electric tug vehicle having its own solar arrays would be appropriate. (Author)

A80-29989 * # **Upper stages utilizing electric propulsion.** D. C. Byers (NASA, Lewis Research Center, Cleveland, Ohio). *Joint Army-Navy-NASA-Air Force Interagency Propulsion Committee, Propulsion Meeting, Monterey, Calif., Mar. 11-13, 1980, Paper.* 19 p. 23 refs.

The payload capabilities of upper stages using electric propulsion for a LEO to GEO orbit transfer mission are discussed. Payloads are calculated using an established methodology which employs assumptions concerning state-of-the-art electric propulsion technology. The effects on payloads are examined for variations of total mass in LEO (MLEO), thrusting (trip) times, propellant type, specific impulse, and power source specific mass. It is found that the ratios of payload masses to total mass in LEO are insensitive to MLEO, which allows a highly condensed presentation of the overall payload capability. Electric stages are shown capable of delivering payloads in thrusting times less than 50 days with the payloads increasing rapidly with increase in thrusting times. Payload capabilities exceeding those attainable with chemical propulsion are possible using state-of-the-art electric propulsion technology. L.M.

N80-11950*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

COST-EFFECTIVE TECHNOLOGY ADVANCEMENT DIRECTIONS FOR ELECTRIC PROPULSION TRANSPORTATION SYSTEMS IN EARTH-ORBITAL MISSIONS

John D. Regetz, Jr. and C. H. Terwilliger (Boeing Aerospace Co., Seattle, Wash.) 1979 21 p ref Presented at the Fourteenth Intern. Conf. on Electric Propulsion, Princeton, N. J., 30 Oct. - 1 Nov. 1979; sponsored by AIAA and Deut. Ges. fur Luft und Raumfahrt

(NASA-TM-79289) Avail: NTIS HC A02/MF A01 CSCL 05C

The directions that electric propulsion technology should take to meet the primary propulsion requirements for earth-orbital missions in the most cost effective manner are determined. The mission set requirements, state of the art electric propulsion technology and the baseline system characterized by it, adequacy of the baseline system to meet the mission set requirements, cost optimum electric propulsion system characteristics for the mission set, and sensitivities of mission costs and design points to system level electric propulsion parameters are discussed. The impact on overall costs than specific masses or costs of propulsion and power systems is evaluated. A.W.H.

N80-15204*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
ANALYSIS OF GaAs AND Si SOLAR CELL ARRAYS FOR EARTH ORBITAL AND ORBIT TRANSFER MISSIONS
Kent D. Jeffries 1980 9 p refs Presented at 14th Photovoltaic Specialists Conf., San Diego, Calif., 7-10 Jan. 1980; sponsored by IEEE
(NASA-TM-81383; E-291) Avail: NTIS HC A02/MF A01 CSCL 21C

Silicon and gallium arsenide arrays were studied and compared for low earth orbit (LE), geosynchronous orbit (GEO), and LEO to GEO electric propulsion orbit transfer missions. The sensitivities of total cost to parameters such as mission duration, array cost, cover glass thickness, and concentration ratio were determined along with cost tradeoffs between silicon and gallium arsenide arrays for selected mission classes. Results indicate that development of the technology for low cost, light weight concentrators should be increased and that cost reduction efforts for gallium arsenide cells be pursued. R.C.T.

N80-17114 Martin Marietta Corp., Denver, Colo.
PROPULSION CONCEPTS FOR SPACE TRANSFER OF LARGE SPACE STRUCTURES
W. E. Pipes *In* APL The 1979 JANNAF Propulsion Meeting, Vol. 1 Mar. 1979 p 489-511 refs

(Contract F04701-77-C-0180)
Avail: Issuing Activity CSCL 21H

Large space structures that will carry solar cell arrays, highpowered communications relay antennas and large aperture sensor systems are considered and evaluated. The propulsion requirements are discussed and the propulsion systems that are compatible with deployable large space structures are defined. The propulsion concept, propellant, configuration, performance capabilities, and state of development are described. R.C.T.

09
FLIGHT EXPERMENTS

Includes controlled experiments requiring high vacuum and zero G environment.

A80-20635 **In-orbit test requirements for initial large space structures /LSS/ demonstration flight.** W. R. Herling (Grumman Aerospace Corp., Bethpage, N.Y.). *Society of Allied Weight Engineers, Annual Conference, 38th, New York, N.Y., May 7-9, 1979, Paper 1289*. 16 p.

The paper discusses three groups of tests planned for the LSS demonstration flight. These are: (1) verification of both the ABB operation and the quality of the beam produced, (2) determining the structural/thermal and structural/dynamic responses of the beam produced by the ABB, and (3) LSS assembly and handling techniques in addition to determination of the satellite's structural response to dynamic and thermal stimuli. In addition, attention is given to the proposed instrumentation required to sense and record the data. Discussion also covers the test sequencing rationale as well as the impact of the test program on overall flight duration. Finally, areas related to the flight tests requiring further development are identified. M.E.P.

N80-21427# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
COATING AND CONTAMINATION EXPERIMENT ON LDEF
L. Preuss and W. Schaefer *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 71-80 refs

(Contracts DFVLR-BPT-01-TD-037-AK/RT; DFVLR-BPT-01-TB-067-B-AK/RT; BMFT-WRT-2076; DFVLR-BPT-01-TD-048-A-AK/RT; BMFT-WRT-2077; DFVLR-BPT-01-TD-019-B-AK/RT; BMFT-WRT-2079)
Avail: NTIS HC A15/MF A01

The lifecycle of geosynchronous satellites was examined in terms of reliable thermal control based on stable second surface mirrors (SSM). Flight measurements showed higher solar absorptance-degradation than measured on the ground. By means of a flight experiment on the long duration exposure facility (LDEF) and additional ground experiments, degradation of thermal coatings (SSMETC) was investigated. The flight experiment as well as the ground experiment test samples and values to be measured are presented. Author (ESA)

N80-21428# Aerospace Corp., El Segundo, Calif.
PRELIMINARY FLIGHT RESULTS FROM P78-2 (SCATHA) SPACECRAFT CONTAMINATION EXPERIMENT
D. F. Hall and A. A. Fote *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 81-90 refs Sponsored by AF

Avail: NTIS HC A15/MF A01

The ML12 experiment was launched to determine if spacecraft charging contributes significantly to the rate that contaminants arrive at exterior spacecraft surfaces. The experiments consisted of two mass detectors and two trays of calorimetrically mounted thermal control coatings samples. Preliminary results from the first 6 months on orbit indicate that the vehicle has gradually accumulated a mass, which has not yet reached a magnitude sufficient to measurably affect solar absorptance of the spacecraft surface materials. Other significant results are reported.
Author (ESA)

10
SOLAR POWER SATELLITE SYSTEM

Includes solar power satellite concepts with emphasis upon structures, materials, and controls.

A80-14791 Earth benefits of solar power satellites. P. E. Glaser (Arthur D. Little, Inc., Cambridge, Mass.). In: Space - The best is yet to come; Proceedings of the Sixteenth Space Congress, Cocoa Beach, Fla., April 25-27, 1979. Cocoa Beach, Fla., Canaveral Council of Technical Societies, 1979, p. 5-11 to 5-25. 25 refs.

The paper presents the potential of solar energy for global needs with emphasis on solar energy conversion in space for use on earth. This approach is compared with terrestrial solar energy conversion methods, and the concept of the solar power satellite (SPS) is presented. The technology options for converting solar energy in space, transmitting power, and converting it on earth into electricity are summarized, and the requirements for space transportation systems, orbital assembly, and maintenance are reviewed. The economic, institutional, and environmental aspects of SPS operations are discussed; a phased SPS development program and possible organizational structures to produce power generation on earth are outlined. A.T.

A80-18800 Cost effectiveness requirements for space power stations. G. K. C. Pardoe (General Technology Systems, Ltd., Brentford, Middx., England). *Acta Astronautica*, vol. 6, Dec. 1979, p. 1745-1752.

The concept of converting solar energy in orbital space stations and transmitting electrical power to Earth at radio frequency, is receiving increasing attention both in paper studies and experimental and development work. The projects conceived are large in scale and implications and will demand major resources in their development and deployment. This paper, therefore, examines the requirements which together will determine the appropriate levels of cost effectiveness of space power stations and should assist in establishing critical or sensitive areas which will influence the operational validity of the concepts. The r.f. transmission of electric power to and from, or between, spacecraft may itself have wider implications and is another aspect considered in the paper. In summary, the paper does not seek to introduce new design concepts, but appraises the situation and exposes indicators concerning cost effectiveness. (Author)

A80-20641 * Weight optimization of ultra large space structures. R. P. Reinert (Boeing Aerospace Co., Seattle, Wash.). *Society of Allied Weight Engineers, Annual Conference, 38th, New York, N.Y., May 7-9, 1979, Paper 1301*. 22 p. 5 refs. Contracts No. NAS9-15196; No. NAS9-15636.

The paper describes the optimization of a solar power satellite structure for minimum mass and system cost. The solar power satellite is an ultra large low frequency and lightly damped space structure; derivation of its structural design requirements required accommodation of gravity gradient torques which impose primary loads, life up to 100 years in the rigorous geosynchronous orbit radiation environment, and prevention of continuous wave motion in a solar array blanket suspended from a huge, lightly damped structure subject to periodic excitations. The satellite structural design required a parametric study of structural configurations and consideration of the fabrication and assembly techniques, which resulted in a final structure which met all requirements at a structural mass fraction of 10%. A.T.

A80-20643 The satellite power system concept and program. G. M. Hanley (Rockwell International Corp., El Segundo, Calif.). *Society of Allied Weight Engineers, Annual Conference, 38th, New York, N.Y., May 7-9, 1979, Paper 1305*. 14 p.

The paper summarizes the approaches that have been considered for the satellite power system (SPS) and the current reference concept defined by NASA and the Department of Energy (DOE). The overall system's characteristics are described. The NASA-DOE reference SPS system consists of two different satellite approaches, both of which utilize solar photovoltaic energy conversion and have 5-GW power outputs on the ground. One approach uses a silicon solar cell array without reflecting concentrators, while the other employs gallium arsenide solar cells in an array with flat concentrators. The approach to satellite construction and transportation system characteristics are also described. V.T.

A80-21908 Space manufacturing, satellite power and human exploration. B. T. O'Leary and G. K. O'Neill (Princeton University, Princeton, N.J.). *Interdisciplinary Science Reviews*, vol. 4, Sept. 1979, p. 193-207. 82 refs.

It is suggested that satellite power stations manufactured from nonterrestrial materials may alleviate the global energy crisis as early as the 1990's. The paper shows that costs may be competitive with coal and nuclear power and could provide an environmentally acceptable, inexhaustible and continuous supply of electricity anywhere on earth. Attention is given to habitats for the work force employed in space manufacturing which would offer a choice of gravities for living and recreation. Finally, recent progress in this field and the interdisciplinary aspects of planning such a program are reviewed. M.E.P.

A80-22833 * # Microwave power beaming for long range energy transfer. E. J. Nalos, W. W. Lund, Jr., O. Denman, and S. M. Rathjen (Boeing Aerospace Co., Seattle, Wash.). In: European Microwave Conference, 8th, Paris, France, September 4-8, 1978, Proceedings. Sevenoaks, Kent, England, Microwave Exhibitions and Publishers, Ltd., 1979, p. 573-578. Contract No. NAS9-15196.

Current studies by NASA have identified space solar power as a potential long term viable candidate for efficient energy transfer at orbital ranges using a microwave beam. This paper will describe some of the power-aperture relationships leading to a potential feasible design of a power beaming system. The topics include a discussion of the system constraints, the transmitter and spaceborne array configuration, and the error budget levied by microwave system requirements. (Author)

A80-23218 Advances in energy systems and technology. Volume 2. Edited by P. Auer (Cornell University, Ithaca, N.Y.). New York, Academic Press, Inc., 1979. 277 p. $26.

The topics covered are: the development of solar power satellites, sea thermal power, the economics and system design for on-site solar energy systems, and models for energy technology assessment. The articles address technological issues or issues in a broader systems context, which are closely related to technological issues. B.J.

A80-23219 The development of solar power satellites. P. E. Glaser (Arthur D. Little, Inc., Cambridge, Mass.; Sunsat Energy Council, Washington, D.C.). In: Advances in energy systems and technology. Volume 2. New York, Academic Press, Inc., 1979, p. 1-48. 49 refs.

The SPS concept is reviewed with particular attention given to technology options for conversion in space (photovoltaic and thermal-electric) and for power transmission to earth (microwave and laser transmission). Also discussed are SPS in the space transportation system, orbital assembly and maintenance, SPS/utility power pool interface, and SPS economic considerations and environmental impacts. B.J.

A80-26003 # **Space-manufactured satellite power systems.** R. H. Miller and D. L. Akin (MIT, Cambridge, Mass.). *Journal of Energy*, vol. 3, Nov.-Dec. 1979, p. 373-375. 6 refs.

The tradeoffs between using lunar rather than terrestrial materials for solar power satellite (SPS) manufacturing are examined, particularly the effects of uncertainties in the two primary cost drivers on these tradeoffs: human productivity in space and the cost of transportation to low earth orbit (LEO). Two cases were chosen for comparison, namely, assembly in LEO from terrestrial materials and transportation of the completed SPS to geosynchronous earth orbit (GEO), and materials refined on the moon but parts manufactured and SPS assembled at GEO. It is found that the tradeoff between the use of lunar or terrestrial materials is critically dependent on productivity in space, with the crossover occurring at about 5 kg/h. J.P.B.

A80-31200 # **Satellite solar power plants (Satelitarne elektrownie sloneczne).** K. Wiewiorowska. *Astronautyka*, vol. 22, no. 6, 1979, p. 20, 21. In Polish.

An international survey revealed that serious effort directed to the construction of orbiting solar power plants cannot be expected earlier than in two decades. The formidable technical and economical problems involved in this venture are examined, along with some legal aspects arising from the current formulation of the international space law. V.P.

N80-10414# Grumman Aerospace Corp., Bethpage, N.Y. System Sciences.

MINIMUM COST TRANSMITTER-RECEIVER ANTENNA PAIRS

G. Moyer and H. Hinz Sep. 1979 26 p refs
(RM-690) Avail: NTIS HC A03/MF A01

There are two types of solutions when applying the optimal control theory to antenna design. The cost (C) is an arbitrary function of the radii of the receiver (R sub 0) and of the transmitter (R sub 1). When the received power (W sub 0) divided by the area is small, as happens in the proposed satellite solar power station (SSPS), the value of the power density at the center of the receiver should be left open. Then the problem simplifies to such an extent that it can be solved with considerable accuracy using only ordinary calculus and graphs provided. The product (R sub 0) (R sub 1) depends only on the power ratio (W sub 0) (W sub 1) and can be obtained from a graph. The radius of the transmitter can then be replaced in the cost function and the best value of the radius of the receiver can be found from dC/d (R sub 0) = 0. The transmitter and receiver power density distributions are proportional and resemble a truncated Gaussian distribution. As W sub 0/sq pi (R sub 0) becomes larger the power density at the center of the receiver reaches its upper limit. After this point the problem must be solved with an additional state variable and constraint using a computer program. Numerical results are presented for the SSPS. A.R.H.

N80-10600*# RCA Labs., Princeton, N. J. David Sarnoff Research Center.

ANALYSIS OF S-BAND SOLID-STATE TRANSMITTERS FOR THE SOLAR POWER SATELLITE Final Report, 1 Nov. 1978 - 1 Jun. 1979

E. F. Belohoubek, M. Ettenberg, H. C. Huang, M. Nowogrodzki, and F. N. Sechi 1 Jun. 1979 79 p refs
(Contract NAS9-15755)
(NASA-CR-160320) Avail: NTIS HC A05/MF A01 CSCL 10A

The possibility of replacing the Reference System antenna in which thermionic devices are used for the dc-to-microwave conversion, with solid-state elements was explored. System, device, and antenna module tradeoff investigations strongly point toward the desirability of changing the transmitter concept to a distributed array of relatively low power elements, deriving their dc power directly from the solar cell array and whose microwave power outputs are combined in space. The approach eliminates the thermal, weight, and dc-voltage distribution problems of a system in which high power tubes are simply replaced with clusters of solid state amplifiers. The proposed approach retains the important advantages of a solid state system: greatly enhanced reliability and graceful degradation of the system. A.R.H.

N80-11121*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.

SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY, PHASE 2. Interim Report

9 Jul. 1979 265 p
(Contract NAS9-15636)
(NASA-CR-160377; D180-25381-1) Avail: NTIS HC A12/MF A01 CSCL 22B

A program plan for the Solar Power Satellite Program is presented. The plan includes research, development, and evaluation phase, engineering and development and cost verification phase, prototype construction, and commercialization. Cost estimates and task requirements are given for the following technology areas: (1) solar arrays; (2) thermal engines and thermal systems; (3) power transmission (to earth); (4) large space structures; (5) materials technology; (6) system control; (7) space construction; (8) space transportation; (9) power distribution, and space environment effects. J.M.S.

N80-11122*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.

SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY, PHASE 2. PART 1: MIDTERM BRIEFING

27 Jun. 1979 543 p
(Contract NAS9-15636)
(NASA-CR-160378; D180-25402-1) Avail: NTIS HC A22/MF A01 CSCL 22B

An overview of the program plan for the Solar Power Satellite Program is given. Progress in the microwave power transmission system is reported. A description is given of the following: (1) launch and recovery site facilities, systems and operations; (2) cargo packaging; (3) earth-to-LEO cargo transportation operations; (4) LEO-to-GEO cargo transportation operations; (5) personnel transportation operations; (6) space vehicles in-space maintenance operations; and (7) SPS maintenance systems and operations. Other topics discussed include GEO base operations, satellite construction operations, intra-base logistics, and GEO base definition. A research and program plan is presented along with cost estimates. J.M.S.

N80-11123*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.

SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY

26 Jul. 1978 161 p Prepared jointly with GE, Schenectady, N.Y. and Grumman, Bethpage, N.Y. and Little (Arthur D.), Boston, Mass. and TRW, Redondo Beach, Calif.
(Contract NAS9-15636)
(NASA-CR-160368; D180-24735-1) Avail: NTIS HC A08/MF A01 CSCL 22B

A synopsis of the study plan for the solar power satellite system is presented. Descriptions of early task progress is reported for the following areas: (1) laser annealing, (2) solid state power amplifiers, (3) rectenna option, (4) construction of an independent electric orbit transfer vehicle, and (5) construction of a 2.5 GW solar power satellite. R.E.S.

N80-12106*# Rockwell International Corp., Downey, Calif. Space Div.

SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY. VOLUME 4: SPS POINT DESIGN DEFINITION Final Report

G. Hanley Apr. 1978 220 p 5 Vol.
(Contract NAS8-32475)
(NASA-CR-150683; SD-78-AP-0023-4-Vol-4) Avail: NTIS HC A10/MF A01 CSCL 22B

The satellite power systems point design concept is described. The concept definition includes satellite, ground and space systems, and their relationships. Emphasis is placed on the

definition of the GaAlAs photovoltaic satellite system. The major subsystems of the satellite system including power conversion, power distribution and control, microwave, attitude control and stationkeeping, thermal control, structures, and information management and control are discussed. A.W.H.

N80-12108*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY. PART 1: MIDTERM BRIEFING Interim Report
19 Oct. 1978 456 p
(Contract NAS9-15636)
(NASA-CR-160369; D180-24872-1; DRL-T-1487; DRD-MA-732T) Avail: NTIS HC A20/MF A01 CSCL 22B

The solar power satellite systems are defined and analyzed. Included are areas of space construction, rectennal construction, rectenna siting, and the aluminum satellite structure. A.W.H.

N80-12109*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY, VOLUME 5. PHASE 2: FINAL BRIEFING Final Report
5 Nov. 1979 640 p
(Contract NAS9-15636)
(NASA-CR-160380; D180-25461-5-Vol-5; DRL-T-1487; DRD-MA-732T) Avail: NTIS HC A99/MF A01 CSCL 22B

A briefing outline of the definition study is presented. Topics discussed include: Solar Power Satellite (SPS) research and development, definition study, operations control, transportation, solid state SPS, pilot link analysis, and offshore space center. F.O.S.

N80-13139*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY. VOLUME 1, PHASE 1: EXECUTIVE SUMMARY Final Report
16 Feb. 1979 29 p Sponsored in part by DOE. Prepared in cooperation with Gen. Elec., Fairfield, Conn., Grumman Aerospace Corp., Bethpage, N. Y., Little (Arthur D.), Inc., Cambridge, Mass., and TRW Defense and Space Systems Group., Redondo Beach, Calif. 7 Vol.
(Contract NAS9-15636)
(NASA-CR-160370; D180-25037-1-Vol-1) Avail: NTIS HC A03/MF A01 CSCL 22B

A systems definition study of the solar satellite system (SPS) is presented. The technical feasibility of solar power satellites based on forecasts of technical capability in the various applicable technologies is assessed. The performance, cost, operational characteristics, reliability, and the suitability of SPS's as power generators for typical commercial electricity grids are discussed. The uncertainties inherent in the system characteristics forecasts are assessed. A.W.H.

N80-13140*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY. VOLUME 2, PHASE 1: SYSTEMS ANALYSES TRADEOFFS. Final Report
1 Mar. 1979 554 p Sponsored in part by DOE. Prepared in cooperation with Gen. Elec., Fairfield, Conn., Grumman Aerospace Corp., Bethpage, N. Y., Little (Arthur D.), Inc., Cambridge, Mass. and TRW Defense and Space Systems Group, Redondo Beach, Calif. 7 Vol.
(Contract NAS9-15636)
(NASA-CR-160371; D180-25037-2-Vol-2) Avail: NTIS HC A24/MF A01 CSCL 22B

A systems definition study of the solar power satellite system is presented. The satellite solar energy conversion and microwave power transmission systems are discussed. Space construction and support systems are examined including a series construction and equipment characteristics analysis. Space transportation for the satellite and the ground receiving station are assessed. A.W.H.

N80-13141*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY. VOLUME 3: REFERENCE SYSTEM DESCRIPTION. PHASE 1 Final Report
1 Apr. 1979 362 p Sponsored in part by DOE. Prepared in cooperation with Gen. Elec., Fairfield, Conn., Grumman Aerospace Corp., Bethpage, N. Y., Little (Arthur D.), Inc., Cambridge Mass., and TRW Defense and Space Systems Group, Redondo Beach, Calif. 7 Vol.
(Contract NAS9-15636)
(NASA-CR-160372; D180-25037-3-Vol-3) Avail: NTIS HC A16/MF A01 CSCL 22B

An analysis of the solar power satellite system is presented. The satellite solar energy conversion and microwave power transmission systems are discussed including the structure, power distribution, thermal control, and energy storage. Space construction and support systems are described including the work support facilities and construction equipment. An assessment of the space transportation system for the satellite and the ground receiving station is presented. A.W.H.

N80-13143*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY. VOLUME 5, PHASE 1: EXECUTIVE SUMMARY Final Briefing
14 Nov. 1979 132 p Sponsored in part by DOE. Prepared in cooperation with Gen. Elec., Fairfield, Conn., Grumman Aerospace Corp., Bethpage, N. Y., Little (Arthur D.), Inc., Cambridge, Mass., TRW Defense and Space Systems Group, Redondo Beach, Calif. 7 Vol.
(Contract NAS9-15636)
(NASA-CR-160374; D180-25037-5-Vol-5) Avail: NTIS HC A07/MF A01 CSCL 22B

An analysis of the solar power satellite system is presented. Performance, cost, and operational characteristics are assessed. The photovoltaic system is described and investigated. Alternative construction concepts are discussed. The structural bay configuration is presented along with the antenna structure options. A.W.H.

N80-13144*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY. VOLUME 6, PHASE 1: SPACE CONSTRUCTION AND TRANSPORTATION Final Briefing
14 Nov. 1979 286 p Sponsored in part by DOE. Prepared in cooperation with Gen. Elec., Fairfield, Conn. Grumman Aerospace Corp., Bethpage, N. Y., Little (Arthur D.), Inc., Cambridge, Mass. and TRW Defense and Space Systems Group, Redondo Beach, Calif. 7 Vol.
(Contract NAS9-15636)
(NASA-CR-160375; D180-25037-6-Vol-6) Avail: NTIS HC A13/MF A01 CSCL 22B

A systems definition study of the solar power satellite is presented. Highlighted are the space construction and space transportation systems. A.W.H.

N80-13145*# Boeing Aerospace Co., Seattle, Wash. Ballistic Missiles and Space Div.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY. VOLUME 7, PHASE 1: SPS AND RECTENNA SYSTEMS ANALYSES Final Briefing
14 Nov. 1979 280 p Sponsored in part by DOE Prepared in cooperation with Gen. Elec., Fairfield, Conn., Grumman Aerospace Corp., Bethpage, N. Y., Little (Arthur D.), Inc., Cambridge, Mass., and TRW Defense and Space Systems Group, Redondo Beach, Calif. 7 Vol.
(Contract NAS9-15636)
(NASA-CR-160376; D180-25037-7-Vol-7) Avail: NTIS HC A13/MF A01 CSCL 22B

A systems definition study of the solar power satellite systems is presented. The design and power distribution of the rectenna system is discussed. The communication subsystem and thermal

control characteristics are described and a failure analysis performed on the systems is reported. A.W.H.

N80-14478# PRC Energy Analysis Co., McLean, Va.
SATELLITE POWER SYSTEM (SPS): AN OVERVIEW OF PROSPECTIVE ORGANIZATIONAL STRUCTURES IN THE SOLAR SATELLITE FIELD
H. G. Edler Oct. 1978 19 p refs
(Contract EG-77-C-01-4024)
(TID-29094) HC A02/MF A01

A literature survey, interviews with acknowledged experts in the fields of organizational entities, space, solar energy, and the SPS concept, and an analysis of these inputs to identify the organizational alternatives and make judgments as to their feasibility to serve as patterns for a future SPS entity are presented. Selection and evaluation criteria were determined to include timeliness, reliability, and adequacy to contribute meaningfully to the U.S. supply; political feasibility (both national and international) and cost-effectiveness (including environmental and other external costs). Based on these criteria, four organizational alternatives are discussed which offer reasonable promise as potential options for SPS. These included three domestic alternatives and one international alternative. DOE

N80-15195*# Boeing Aerospace Co., Seattle, Wash.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY. VOLUME 1: EXECUTIVE SUMMARY
Nov. 1979 39 p Prepared in cooperation with General Elec. Co., Fairfield, Conn.; Grumman Aerospace Corp., N. Y.; Little (Arthur D.), Inc., Cambridge, Mass.; TRW, Inc., Cleveland, Ohio; Brown and Root, Inc., Houston, Tex.
(Contract NAS9-15636)
(NASA-CR-160442; D180-25461-1) Avail: NTIS HC A03/MF A01 CSCL 11B

Configuration concepts, option sizes, and systems definitions study design evolutions are reviewed. The main features of the present reference design silicon solar cell solar power satellite are described, as well as the provisions for space construction and support systems. The principal study accomplishments and conclusions are summarized according to the following tasks: (1) baseline critique; (2) construction and maintenance; (3) industrial complex needs, cost estimates, and production capacity; (4) launch complex requirements at KSC or at an offshore facility; (5) integration of the SPS/ground power network; (6) technology advancement and development; (7) costs and schedules; and (8) exploratory technology: laser annealing of solar cells degraded by proton irradiation, and a fiber-optic phase distribution link at 980 MHz. A.R.H.

N80-16086*# Boeing Aerospace Co., Seattle, Wash.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY, PHASE 2. VOLUME 2: REFERENCE SYSTEM DESCRIPTION
Nov. 1979 464 p 5 Vol.
(Contract NAS9-15636)
(NASA-CR-160443; D180-25461-2) Avail: NTIS HC A20/MF A01 CSCL 22B

System descriptions and cost estimates for the reference system of the solar power satellite program are presented. The reference system is divided into five principal elements: the solar power satellites; space construction and support; space and ground transportation; ground receiving stations; and operations control. The program scenario and non-recurring costs are briefly described. R.E.S.

N80-16484*# National Aeronautics and Space Administration, Washington, D. C.
SATELLITE POWER SYSTEM (SPS)
Henry G. Edler Oct. 1978 20 p refs
(Contract EG-77-C-02-4042)
(NASA-TM-80943; TID-29094) Avail: NTIS HC A02/MF A01 CSCL 10A

Potential organizational options for a solar power satellite system (SPS) were investigated. Selection and evaluation criteria were determined to include timeliness, reliability, and adequacy to contribute meaningfully to the U.S. supply; political feasibility (both national and international); and cost effectiveness (including environmental and other external costs). Based on these criteria, four organizational alternatives appeared to offer reasonable promise as potential options for SPS. A large number of key issues emerged as being factors which would influence the final selection process. Among these issues were a variety having to do with international law, international institutions, environmental controls, economics, operational flexibility, congressional policies, commercial-vs-governmental ownership, national dedication, and national and operational stategic issues. R.E.S.

N80-17123*# LinCom Corp., Pasadena, Calif.
A GROUND BASED PHASE CONTROL SYSTEM FOR THE SOLAR POWER SATELLITE, VOLUME 4 Final Report
C. M. Chie Jan. 1980 66 p refs
(Contract NAS9-15782)
(NASA-CR-160458; TR-0180-0779) Avail: NTIS HC A04/MF A01 CSCL 22B

A ground phase control system is studied as an alternative approach to the current reference retrodirective phase control system in order to simplify the spaceborne hardware requirement. Based on waveform selections, functional subsystems to implement the ground-based phase control concept are identified and functionally represented. It was concluded that the feasibility of the concept becomes unclear if the conditions of the ionosphere and satellite motion are not met. M.M.M.

N80-18560*# LinCom Corp., Pasadena, Calif.
A GROUND BASED PHASE CONTROL SYSTEM FOR THE SOLAR POWER SATELLITE. EXECUTIVE SUMMARY, VOLUME 1, PHASE 3 Final Report
C. M. Chie Jan. 1980 51 p refs
(Contract NAS9-15782)
(NASA-CR-160536; TR-0180-0779-Vol-1-Phase-3) Avail: NTIS HC A04/MF A01 CSCL 10B

The Solar Power Satellite (SPS) concept and the reference phase control system investigated in earlier efforts are reviewed. A summary overview of the analysis and selection of the pilot signal and power transponder design is presented along with the SOLARSIM program development and the simulated SPS phase control performance. Evaluations of the ground based phase control system as an alternate phase control concept are summarized. R.E.S.

N80-18561*# LinCom Corp., Pasadena, Calif.
SPS PILOT SIGNAL DESIGN AND POWER TRANSPONDER ANALYSIS, VOLUME 2, PHASE 3 Final Report
W. C. Lindsey, R. A. Scholtz, and C. M. Chie Jan. 1980 106 p refs
(Contract NAS9-15782)
(NASA-CR-160537; TR-0180-0779-Vol-2-Phase-3) Avail: NTIS HC A06/MF A01 CSCL 10B

The problem of pilot signal parameter optimization and the related problem of power transponder performance analysis for the Solar Power Satellite reference phase control system are addressed. Signal and interference models were established to enable specifications of the front end filters including both the notch filter and the antenna frequency response. A simulation program package was developed to be included in SOLARSIM to perform tradeoffs of system parameters based on minimizing the phase error for the pilot phase extraction. An analytical model that characterizes the overall power transponder operation was developed. From this model, the effects of different phase noise disturbance sources that contribute to phase variations at the output of the power transponders were studied and quantified. Results indicate that it is feasible to hold the antenna array phase error to less than one degree per power module for the type of disturbances modeled. R.E.S.

N80-18566*# LinCom Corp., Pasadena, Calif.
ANALYTICAL SIMULATION OF SPS SYSTEM PERFORMANCE, VOLUME 3, PHASE 3 Final Report

A. V. Kantak and W. C. Lindsey Jan. 1980 91 p refs
(Contract NAS9-15782)
(NASA-CR-160538; TR-0180-0779-Vol-3-Phase-3) Avail: NTIS HC A05/MF A01 CSCL 10B

The simulation model for the Solar Power Satellite spaceantenna and the associated system imperfections are described. Overall power transfer efficiency, the key performance issue, is discussed as a function of the system imperfections. Other system performance measures discussed include average power pattern, mean beam gain reduction, and pointing error. R.E.S.

N80-19616*# Boeing Aerospace Co., Seattle, Wash.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY. VOLUME 3: OPERATIONS AND SYSTEMS SYNTHESIS, PHASE 2 Final Report, Jan. - Nov. 1979
Nov. 1979 596 p refs 5 Vol.
(Contract NAS9-15636)
(NASA-CR-160480; D180-25461-3) Avail: NTIS HC A25/MF A01 CSCL 10A

The results of the operations analyses are reported. Some of these analyses examined operations aspects of space vehicle in-space maintenance. Many of the analyses explored in great depth operations concerned the LEO Base cargo handling operations. Personnel transportation operations and cargo packaging were also analyzed. These operations analyses were performed to define the operational requirements for all of the SPS system elements so that equipment and facilities could be synthesized, and to make estimates of the manpower requirements. An overall, integrated, end-to-end description of the SPS operations is presented. The detailed operations analyses, upon which this integrated description was based, are included. F.O.S.

N80-19631*# Boeing Aerospace Co., Seattle, Wash.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY. VOLUME 1, PHASE 2: EXECUTIVE SUMMARY Final Report
Nov. 1979 36 p Revised
(Contract NAS9-15636)
(NASA-CR-160540; D180-25461-1-Vol-1-Rev-A) Avail: NTIS HC A03/MF A01 CSCL 10A

A review of solar energy conversion and utilization is presented. The solar power satellite system is then described. Overall system definition and integration is discussed. Principal reference system study accomplishments and conclusions are presented. R.E.S.

N80-19658# National Technical Information Service, Springfield, Va.
SOLAR ELECTRIC POWER GENERATION, VOLUME 2. CITATIONS FROM THE NTIS DATA BASE Progress Report, 1976 - Sep. 1978
Audrey S. Hundemann Dec. 1979 235 p
(PB80-803000) Avail: NTIS HC $30.00/MF $30.00 CSCL 10B

Citations of Federally-funded research are presented pertaining to electric power generation by both direct conversion with solar cells and indirect conversion using solar heat. Topic areas cover equipment design, site surveys, economics, and feasibility studies of solar power satellite systems, photovoltaic systems, solar total energy systems, and central receiver solar thermal power systems. A few abstracts deal with phase change materials and thermal energy storage systems. This updated bibliography contains 228 abstracts, none of which is new to the previous edition. GRA

N80-19659# National Technical Information Service, Springfield, Va.
SOLAR ELECTRIC POWER GENERATION, VOLUME 3. CITATIONS FROM THE NTIS DATA BASE Progress Report, Oct. 1978 - Nov. 1979
Audrey S. Hundemann Dec. 1979 141 p Supersedes NTIS/PS-78/1108; NTIS/PS-77/0898; NTIS/PS-76/0796; NTIS/PS-75/691; NTIS/PS-75/346
(PB80-803018; NTIS/PS-78/1108; NTIS/PS-77/0898; NTIS/PS-76/0796; NTIS/PS-75/691; NTIS/PS-75/346) Avail: NTIS HC $30.00/MF $30.00 CSCL 10B

Equipment design, site surveys, economics, and feasibility studies of solar power satellite systems, photovoltaic systems, solar total energy systems, and central receiver solar thermal power systems are discussed in the 134 Federally-sponsored research reports cited in this updated bibliography. All entries are new to the previous edition. GRA

N80-21395*# Boeing Aerospace Co., Seattle, Wash.
SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY, VOLUME 4, PHASE 2 Final Report, Jan. - Nov. 1979
Dec. 1979 308 p refs Sponsored in part by DOE
(Contract NAS9-15636)
(NASA-CR-160565; D180-25461-4) Avail: NTIS HC A14/MF A01 CSCL 22B

Results of an overall evaluation of the solar power satellite concept are reported. Specific topics covered include: solid state sandwich configuration; parametric development of reliability design; power distribution system for solid state solar power satellites; multibeam transmission; GEO base system configuration; suppression of the heavy lift launch vehicle trajectory; conceptual design of an offshore space center facility; solar power satellite development and operations scenario; and microwave power transmission technology, advancement, development, and facility requirements. J.M.S.

N80-21880# Technische Univ., Berlin (West Germany). Institut fuer Luft- und Raumfahrt.
STUDY ON EUROPEAN ASPECTS OF SOLAR POWER SATELLITES, VOLUME 1 Final Report
J. Ruth and W. Westphal Jun. 1979 137 p refs
(Contract ESA-3705/78-F-DK(SC))
(ESA-CR(P)-1266) Avail: NTIS HC A07/MF A01

A study on implications of the potential electricity supply for Western Europe by Solar Power Satellites (SPS) and of their implementation problems around the turn of the century is presented. Three objectives in this scope have been pursued to provide a decision platform for on-going study and research activities: (1) to establish an information base including relevant data collection and basic SPS-systems understanding; (2) to identify and preliminary assess specific European problems of SPS utilization; and (3) to accomplish recommendations for early study activities of particular European concern. The last item is directly derived from the evaluations of the second study objective and must be seen in the context with SPS activities of the USA. It is concluded that the special European environment calls for special European utilization feasibility analyses, while the principal technical feasibility of a SPS-system should be taken over from U.S. studies. Moreover, if the USA stops its activities, an implementation of a SPS-system for Western Europe would be impractical in the considered time frame (2000-2030). Author (ESA)

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GENERAL

Includes either state-of-the-art or advanced technology which may apply to Large Space Systems and does not fit within the previous nine categories. Shuttle payload requirements, on-board requirements, data rates, and shuttle interfaces, and publications of conferences, seminars, and workshops will be covered in this area.

A80-14771 **Space - The best is yet to come; Proceedings of the Sixteenth Space Congress, Cocoa Beach, Fla., April 25-27, 1979.** Congress sponsored by the Canaveral Council of Technical Societies. Cocoa Beach, Fla., Canaveral Council of Technical Societies, 1979. 325 p. $30.

Papers are presented on such areas as Shuttle update, DOD initiatives in space, Spacelab, payload planning, space commercialization, and technology transfer. Particular consideration is given to the Shuttle orbital flight test, leased military space communication systems, Spacelab flight operations, commercialization of materials processing in space, and medical applications of aerospace technology. B.J.

A80-17500 * **Overview of NASA solar physics programs.** E. Chipman (NASA, Office of Space Science, Solar Terrestrial Div., Washington, D.C.). In: Space optics: Imaging X-ray optics workshop; Proceedings of the Seminar, Huntsville, Ala., May 22-24, 1979. Bellingham, Wash., Society of Photo-Optical Instrumentation Engineers, 1979, p. 256-263.

The program of solar physics missions for the 1980's will include earth-orbiting and solar-orbiting free flying satellites as well as Shuttle sorties carrying large facility instruments and smaller PI-class investigations. Individual missions will have specific, unifying objectives in contrast to the exploratory nature of missions of the 1960's and 70's. The Solar Maximum Mission will study solar flares in 1980 and 1981. The International Solar Polar Mission will swing past Jupiter and traverse the Sun's polar caps in 1986, measuring the high-latitude solar wind. Three of the early Shuttle flights will carry PI-class solar experiments, and the Solar Optical Telescope, to fly in about 1984, will provide extremely high spatial resolution of solar features. Possible future missions include the Solar Cycle and Dynamics Mission to study the Sun's magnetic cycle, and the Solar Probe, which will pass within 4 solar radii of the Sun's surface. (Author)

A80-18320 # **Characteristics of electrical discharges on the P78-2 satellite /SCATHA/.** H. C. Koons (Aerospace Corp., Space Sciences Laboratory, El Segundo, Calif.). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 18th, Pasadena, Calif., Jan. 14-16, 1980, Paper 80-0333.* 8 p. Contract No. F04701-79-C-0080.

The P78-2 (SCATHA) satellite was launched on 30 January 1978 to measure the characteristics of the spacecraft charging process near synchronous orbit. A Charging Electrical Effects Analyzer onboard measures the characteristics of electrical discharges in both the frequency and time domain. Pulses are detected in response to commands, during electron and ion beam operations and during natural charging events. (Author)

A80-18797 **Space light - Space industrial enhancement of the solar option.** K. A. Ehricke (Space Global, La Jolla, Calif.). *Acta Astronautica,* vol. 6, Dec. 1979, p. 1515-1633. 34 refs.

The paper considers space light systems which provide an opportunity for the application of space technology to the enhancement of the solar energy uses in industrial countries. The space light functions range from night illumination of rural and urban areas (Lunetta systems) to photosynthetic production enhancement for the growth of food and biomass for conversion to chemical fuels; to electric power generation by irradiating photovoltaic or thermal ground receivers at night or by adding to the natural solar energy input in daytime (Soletta systems). The Lunetta and Solletta concepts are reviewed, and an assessment of terrestrial alternatives is made; the Lunetta, Powersolletta, and a large Biosolletta space light systems are selected for large-scale seafood production in Antarctic and Arctic waters. Models are developed for rural and urban lighting, power generation with photovoltaic and thermal ground stations, and for the large-scale production of seafood. A.T.

A80-19774 * **NASCAP modelling of environmental-charging-induced discharges in satellites.** N. J. Stevens and J. C. Roche (NASA, Lewis Research Center, Cleveland, Ohio). *(IEEE, U.S. Defense Nuclear Agency, and Jet Propulsion Laboratory, Annual Conference on Nuclear and Space Radiation Effects, 16th, Santa Cruz, Calif., July 17-20, 1979.) IEEE Transactions on Nuclear Science,* vol. NS-26, Dec. 1979, p. 5112-5120. 22 refs.

A study of the charging and discharging characteristics of a typical geosynchronous satellite experiencing time-varying geomagnetic substorms, in sunlight, is conducted. The NASA Charging Analyzer Program (NASCAP) is used. An electric field criteria of 1.5 x 10 to the 5th volts/cm to initiate discharges and transfer of 67% of the stored charge is used in this study, based on ground test results. The substorm characteristics are arbitrarily chosen to evaluate effects of electron temperature and particle density (which is equivalent to current density). It has been found that while there is a minimum electron temperature for discharges to occur, the rate of discharges is dependent on particle density and duration times of the encounter. Hence, it is important to define the temporal variations in the substorm environments. (Author)

A80-21782 * **Space Transportation System - Status report.** L. R. Scherer (NASA, Kennedy Space Center, Cocoa Beach, Fla.). *British Interplanetary Society, Journal (Space and Education),* vol. 32, Oct. 1979, p. 364-370.

A series of detailed illustrations present graphically the status of the STS. The Shuttle vehicle is compared to other expendable vehicles hitherto used by NASA, and data on the Shuttle's components and dimensions and weights are provided. Also presented is the mission profile for the Shuttle and the installation of Spacelab into the Orbiter. Illustrations cover the steps of the vehicle preparation for launch and a chart is given representing current plans for the launch of various payloads. Finally, the automated beam builder for aluminum beams, orbital test of a space machine for fabrication of structural elements or beams and a multibeam communications antenna, which can be used for very small receivers, are described. L.M.

A80-23525 **Effect of solar power satellite transmissions on radio-astronomical research.** B. Anderson and B. Lovell (Manchester, Victoria University, Jodrell Bank, England). *(Royal Society, Discussion on Solar Energy, London, England, Nov. 15, 16, 1978.) Royal Society (London), Philosophical Transactions, Series A,* vol. 295, no. 1414, Feb. 7, 1980, p. 507-511. 5 refs.

The paper examines the use of solar powered satellites as an additional energy source. Calculations indicate that severe restrictions will be placed on the use of radio telescopes on earth for the study of radio emission from celestial objects. It is determined that for a single solar powered satellite it would be possible to operate with the receiver protected by suitable filters at radio frequencies well separated from 2.45 GHz and at angles of look well displaced from the satellite. C.F.W.

A80-28028 * # **The geostationary radiation environment.** E. G. Stassinopoulos (NASA, Goddard Space Flight Center, National Space Science Data Center, Greenbelt, Md.). *Journal of Spacecraft and Rockets,* vol. 17, Mar.-Apr. 1980, p. 145-152. 11 refs.

A study of the geostationary radiation environment is presented. The distribution of charged particles is reviewed in terms of

population domains, where trapped constituents (energetic electrons and protons) and transients (solar flare protons) have been considered. Synchronous geomagnetic geometry is discussed, and temporal and spatial variations of trapped particles are briefly reviewed. A short description of the current standard environment models is given. Probabilistic solar flare proton predictions are described, including the distinction between ordinary event and anomalously large event fluences and the probability of occurrence of anomalously large events. A special solar proton evaluation approach is suggested for extended manned missions in the synchronous altitude regime. Finally, calculational results are presented for orbital flux integrations and dose and shielding evaluations. The data, given in graphic and tabular form, are explained and discussed. (Author)

A80-28573 # **A method of controlling orbits of geostationary satellites with minimum fuel consumption.** K. Takahashi. *Radio Research Laboratories, Review,* vol. 25, Mar. 1979, p. 23-29. In Japanese, with abstract in English.

A method of controlling orbits of geostationary satellites with minimum fuel consumption is presented. The orbital angular velocity of a stationary satellite expresses the perturbation on an orbit of the satellite, and produces an agreement between the minimum variation in direction of this velocity with the minimum fuel consumption to maintain a stationary satellite within allocated bounds. The directional variation of the orbital angular velocity is minimized by maintaining the ascending node of the orbit in the direction of the vernal equinox. The direction of the ascending node with minimum fuel consumption to maintain the orbit are given over the 18.6 year nodal period of the moon; the inclination variation of the orbit and the angular speed proportional to the amount of fuel to maintain the orbit over this period are also given. A.T.

A80-28696 **Space Shuttle: Dawn of an era; Proceedings of the Twenty-sixth Annual Conference, Los Angeles, Calif., October 29-November 1, 1979. Parts 1 & 2.** Conference sponsored by the American Astronautical Society. Edited by W. F. Rector, III (TRW, Inc., Redondo Beach, Calif.) and P. A. Penzo (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). San Diego, Calif., American Astronautical Society (Advances in the Astronautical Sciences. Volume 41, Pts. 1 & 2); Univelt, Inc., 1980. Pt. 1, 451 p.; pt. 2, 525 p. Price of part one, $30.; part two, $35.

Aspects of the Space Shuttle program are considered with attention given to DOD applications, the role of the astronaut, industry in space, large platforms in space, the Space Transportation System, and the second generation Shuttle. Also considered are small self-contained payloads, attached payloads, free flying science payloads, free flying applications payloads, space medicine and life sciences, international payloads, and deep-space payloads. B.J.

A80-29526 **Communications Satellite Systems Conference, 8th, Orlando, Fla., April 20-24, 1980, Technical Papers.** Conference sponsored by the American Institute of Aeronautics and Astronautics. New York, American Institute of Aeronautics and Astronautics, Inc., 1980. 792 p. $85.

Present developments and future trends in communication satellite (CS) technology are presented. The GEO-SPAS platform, a third generation CS concept, is discussed. Network and control for tactical CS systems is considered along with emergency response CS systems, digital facsimile communication over satellite links and high-speed satellite data transmission of maritime seismic data. Attention is given to satellite broadcasting, antenna design, and international systems. V.T.

A80-29552 # **Longitude-Reuse Plan doubles communication satellite capacity of geostationary arc.** D. v. Z. Wadsworth (Hughes Aircraft Co., El Segundo, Calif.). In: Communications Satellite Systems Conference, 8th, Orlando, Fla., April 20-24, 1980, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1980, p. 198-204. (AIAA 80-0507)

Communication satellites placed in the geostationary orbital arc must be separated by at least 3 to 4 deg in longitude to avoid mutual interference. The demand for C and Ku band longitude slots will soon exceed the capacity of the arc. Relief can be provided by the Longitude-Reuse Plan which permits doubling or tripling the number of satellites while meeting mutual interference constraints. Three or four satellites in slightly inclined orbits occupy the same orbital arc longitude slot, replacing or augmenting an existing geostationary satellite. By handing over the communications links at times of close approach, these satellites are used to create two full time 'virtual' communications satellites, one remaining north of the equatorial plane and the other south. (Author)

A80-29751 * # **Initial comparison of SSPM ground test results and flight data to NASCAP simulations.** N. J. Stevens, J. V. Staskus, J. C. Roche (NASA, Lewis Research Center, Cleveland, Ohio), and P. F. Mizera (Aerospace Corp., Space Sciences Laboratory, Los Angeles, Calif.). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 18th, Pasadena, Calif., Jan. 14-16, 1980, Paper 80-0336.* 16 p. 23 refs.

The satellite surface potential monitor (SSPM) has been developed for the P78-2 SCATHA (Spacecraft Charging At The High Altitudes) satellite to determine the response of selected spacecraft materials to charged-particle environmental fluxes. Since the monitor infers total surface voltages from a single point on the interior side of insulators, a ground simulation program was undertaken to develop analytical techniques to model the monitors and to obtain an experimental calibration of the relationship between the flight measurement techniques and actual measurements. The experimental testing was conducted using monoenergetic electron beams irradiating samples in the dark. An analytical computer model was developed in the NASCAP (NASA Charging Analyzer Program) code. The analytical model material properties for Kapton that controlled backscatter and secondary yield were adjusted to obtain a single set of values that produced reasonable fits for both voltages and currents. The analytical techniques developed in the ground technology investigation have been applied to space flight conditions. Predictions were compared with limited flight data. The agreement is very good indicating that the technique, and NASCAP, can be used to predict spacecraft material charging behavior. Details of the testing, the analytical modelling technique and flight data comparisons are presented. (Author)

A80-30604 # **Large space systems - Problems and prospects.** C. Q. Christol. In: Colloquium on the Law of Outer Space, 22nd, Munich, West Germany, September 16-22, 1979, Proceedings. New York, American Institute of Aeronautics and Astronautics, Inc., 1980, p. 275-281. 33 refs.

Large space systems are discussed relative to scientific and technological problems, legal problems, and political problems. The position reflected in the present assessment of the future of large space systems is that issues attending the development of such systems are more likely to be political and legal than physical. With respect to large space systems, it is necessary to combine in an analysis of their future utility both the functions in which they may be expected to engage and the spatial areas in which they may orbit. At present the world community lacks experience with the multinational management of technologically based programs on a global scale. S.D.

A80-30605 # **Outer space activities versus outer space.** L. Perek. In: Colloquium on the Law of Outer Space, 22nd, Munich, West Germany, September 16-22, 1979, Proceedings. New York, American Institute of Aeronautics and Astronautics, Inc., 1980, p. 283-286. 5 refs.

The need for large satellites and space stations arises from the success in space communications, space meteorology, and remote sensing from satellites. In the future space communications will most probably use large stations, antenna farms, with exchangeable

components. At present, with approximately 1000 earth-orbiting satellites the only important relation between satellites is in the proper use of the frequency spectrum for communications. This question is very efficiently handled within the ITU. Attention is focused on a discussion of various aspects of collision of space objects, including large and small debris. Ways of reducing the number of collisions are identified. Also considered are collisions of space objects with the earth. Space missions should be planned until their actual termination not just up to the useful life of space objects. S.D.

A80-31656 **Dynamics and control of large flexible spacecraft; Proceedings of the Second Symposium, Blacksburg, Va., June 21-23, 1979.** Symposium sponsored by the Virginia Polytechnic Institute and State University and American Institute of Aeronautics and Astronautics. Edited by L. Meirovitch (Virginia Polytechnic Institute and State University, Blacksburg, Va.). Blacksburg, Va., Virginia Polytechnic Institute and State University, 1979. 734 p. $30.

General topics that are presented include controls, structural dynamics, system identification and filtering, adaptive control, system truncation, development dynamics and modal control. Individual subjects include controller design approaches for large space structures using LQG control theory, optimal large angle single axis rotational maneuvers of flexible spacecraft, on controllability of a long flexible beam in orbit, fast visualization of the results of structural dynamics calculations as well as a new concept in adaptive structural control. C.F.W.

N80-13125# General Accounting Office, Washington, D. C.
THE NEAR-TERM POTENTIAL OF MANUFACTURING IN SPACE
E. Fritts and A. Byroade *In* ESA Mater. Sci. in Space Jun. 1979 p 427-432
Avail: NTIS HC A20/MF A01; ESA, Paris FF 120

The near-term potential of space manufacturing is discussed. Near-term is defined as anytime between now and the year 2000. In response to that request, an overview of the National Aeronautics and Space Administration's materials processing program, a first step toward space manufacturing, is provided. It is presented in nontechnical terms. The views given represent the perspectives of 52 American scientists, economists, and industrialists who contributed to the study. Problems and obstacles that stand in the way of progress are identified, and some alternative courses of action are offered. Author (ESA)

N80-15184# Committee on Science and Technology (U. S. House).
INTERNATIONAL SPACE ACTIVITIES, 1979
Washington GPO 1979 250 p refs Hearings before the Subcomm. on Space Sci. and Applications of the Comm. on Sci. and Technol., 96th Congr., 1st Sess., 5-6 Sep. 1979
(GPO-53-451) Avail: Subcom. on Space Sci. and Applications

International space activities in the year 1979 are reviewed. Among the subjects discussed are broadcasting satellite service, solar power satellites, radio astronomy, technology development, and future directions in space research. A.W.H.

N80-16094*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
COMPUTED VOLTAGE DISTRIBUTIONS AROUND SOLAR ELECTRIC PROPULSION SPACECRAFT
N. John Stevens 1979 20 p refs Presented at 14th Intern. Conf. on Elec. Propulsion, Princeton, N.J., 30 Oct. - 1 Nov. 1979; sponsored by AIAA and DGLR
(NASA-TM-79286; E-225) Avail: NTIS HC A02/MF A01 CSCL 22B

The NASA Charging Analyzer Program is used to conduct preliminary computations of the voltage distributions around such large spacecraft in geomagnetic substorm environments at geosynchronous altitudes. Both a standard operating voltage (+ or - 150 volts on solar arrays) and direct-drive (+1200 volts on arrays) configurations are considered. Thruster-off simulations are computed for both operating voltage configurations while the effect of simulated thruster-on conditions are evaluated only for direct-drive configuration. These simulated thruster-on conditions are evaluated only for direct-drive configuration. These simulated thruster operations appear to alleviate surface charging. M.M.M.

N80-18074*# National Aeronautics and Space Administration, Washington, D. C.
THE WORLD OF TOMORROW: AEROSPACE ACTIVITIES FOR 8- TO 10-YEAR OLDS. A GUIDE FOR LEADERS OF CHILDREN'S GROUPS AND TEACHERS OF THE LOWER GRADES
1978 70 p Prepared in cooperation with the Boy Scouts of America, Dallas/Fort Worth Airport, Tex.
(NASA-EP-144) Avail: NTIS MF A01; SOD HC CSCL 22A

During January 1977, NASA helped the Cub Scout Division of the Boy Scouts of America in the conduct of its The World of Tomorrow monthly theme. In this period, 249 Cub Scout packs participated in a nationwide aerospace activities project, a pilot project in which den leaders and Cubmasters conducted local programs for their Cub Scouts and Webelos Scouts. The products of these local programs are presented with the written accounts submitted by adult leaders and written compositions, pictures, and photographs of models submitted by the youngsters. A.W.H.

N80-19145*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
LARGE SPACE SYSTEMS TECHNOLOGY, 1979
James C. Ward, Jr., comp. Feb. 1980 487 p refs Ann. Program Tech. Rev. (1st) held at Hampton, Va., 7-8 Nov. 1979
(NASA-CP-2118; L-13488) Avail: NTIS HC A21/MF A01 CSCL 22B

Items of technology and developmental efforts in support of the large space systems technology programs are described. The major areas of interest are large antennas systems, large space platform systems, and activities that support both antennas and platform systems.

N80-21434*# Jet Propulsion Lab., California Inst. of Tech., Pasadena. Applied Mechanics Technology Div.
CONTAMINATION ENHANCED ELECTROSTATIC DISCHARGE MECHANISMS
J. A. Jeffrey and C. R. Maag *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 145-158 refs Sponsored by NASA
Avail: NTIS HC A15/MF A01 CSCL 22B

The two problems of enhanced electrostatic discharge (ESD) and contamination are discussed. It is shown that there is a synergistic relationship between them such that one enhances the probability of occurance of the other. The action of both provides substantially more deleterious affects than the effects of both separately. Mechanisms for such a relationship are discussed as well as application to large advanced technology systems. Author (ESA)

N80-21439# European Space Research and Technology Center, Noordwijk (Netherlands).
ELECTROSTATIC CHARGING AND SPACE MATERIALS
J. Bosma and F. Levadou *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 189-207 refs
Avail: NTIS HC A15/MF A01

The relevance of electrostatic cleanliness aspects of materials is addressed. There has been extensive progress in the study of the effects of electrostatic charging in thermal control coatings, and from the materials points of view electrostatic cleanliness can be implemented in a cost effective manner on future spacecraft projects. The materials are discussed on the basis of experimental data obtained in-house or under ESA contract. A survey of the

on-going activities in several major European laboratories on electrostatic charging is presented. Author (ESA)

N80-21440# Toronto Univ. (Ontario). Dept. of Electrical Engineering.

SURFACE DISCHARGE ARC PROPAGATION AND DAMAGE ON SPACECRAFT DIELECTRICS

K. G. Balmain *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 209-215 refs

(Grant NRC-A-4140)

Avail: NTIS HC A15/MF A01

The propagation of a surface discharge arc or flash over on dielectrics such as Mylar, Teflon, and Kapton is reported. A propagation mechanism is discussed, in which the progress of the surface arc is controlled by the rate of removal of excess charge along filamentary tunnels filled with an overdense plasma of ionized discharge debris. Supporting evidence is drawn from area scanning measurements of discharge electrical properties, and from microscope photographs of permanent damage in the form of submicron diameter subsurface tunnels and surface grooves. Author (ESA)

N80-21441# Electrical Research Association, Leatherhead (England).

THE CHARGING AND DISCHARGING OF SPACECRAFT DIELECTRICS

D. K. Davies *In* ESA Spacecraft Mater. in Space Environ. Dec. 1979 p 217-223 refs

Avail: NTIS HC A15/MF A01

The analysis of spacecraft charging under electron and ion bombardment are discussed. The processes underlying charge equilibration in insulators under electron bombardment, which include backscattering, secondary emission and radiation induced conductivity, are reviewed. It is shown that the contribution of each of these processes is not unequivocally established. The observed discharges are described in terms of a demonstrable dependence of insulator electrical breakdown on indeterminate structural defects of impurities. The conceptual conditions for minimizing charge levels are also discussed but the prime conclusion is, however, that further experimental investigations must precede practical solutions. Author (ESA)

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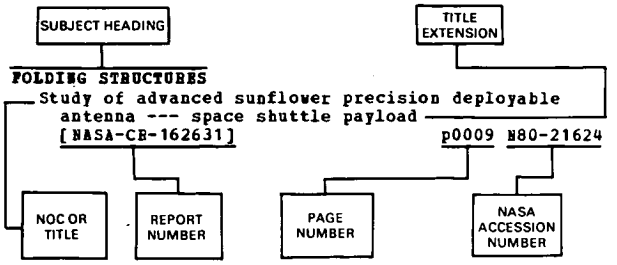

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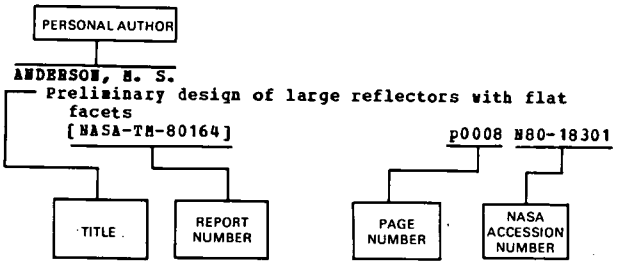

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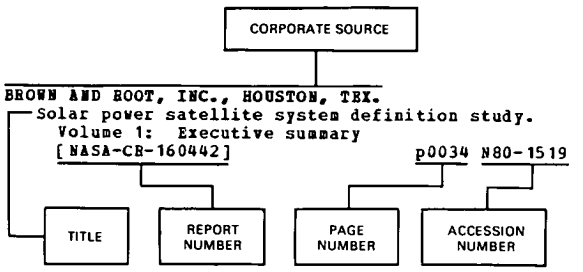

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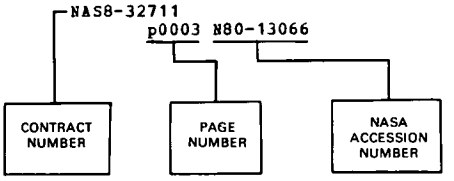

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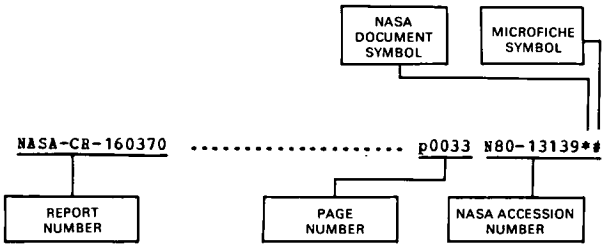

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16. Abstract

This bibliography lists 217 reports, articles, and other documents introduced into the NASA scientific and technical information system between January 1, 1980 and June 30, 1980. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design in the area of the Large Space Systems Technology (LSST) Program. Subject matter is grouped according to systems, interactive analysis and design, structural concepts, control systems, electronics, advanced materials, assembly concepts, propulsion, solar power satellite systems, and flight experiments.

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